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# EXTENDED LIFE HOT MIX ASPHALT PAVEMENT (ELHMAP) TEST SECTIONS AT ATREL

Prepared By

**S. H. Carpenter**
University of Illinois at Urbana-Champaign

Research Report FHWA-ICT-08-017

A report of the findings of

**ICT-R39**
**Validation of Design Concepts for Extended Life Hot Mix Asphalt Pavements (ELHMAP)**

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Study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. Abstract

Project IHR-R39, titled “Validation of Design Concepts for Extended Life Hot Mix Asphalt Pavements (ELHMAP), was funded by the Illinois Department of Transportation (IDOT) to develop data in support of the philosophy of design and performance of the newly proposed concept of Perpetual Pavements (PP). The concept of a PP was to have a rut resistant surface, a fatigue-resistant asphalt rich lower layer, and sufficient total thickness to eliminate the development of fatigue cracking. The IDOT vision of this concept was to have a rut-resistant surface layer, an intermediate layer of a typical IDOT mix, and a lower layer that may or may not need to be asphalt rich. The total thickness would produce a tensile strain at the bottom of the asphalt layers that is below 70 micro strain during the hottest period of the year.

Because this philosophy is a significant deviation from current design principles, and with the introduction of the new Superpave mixes, a significant part of this project was to construct full-scale pavement sections representative of the ELHMAP design approach that could be tested for response variables under Falling Weight Deflectometer (FWD) and full-scale wheel loads. This report details the construction and composition of the sections of various thicknesses over aggregate subbase and lime-modified subgrade.

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# TABLE OF CONTENTS

# ABSTRACT


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## ACKNOWLEDGEMENTS

This publication is based on the results of IHR-R39, “Validation of Design Principles of Extended Life Hot Mix Asphalt Pavements.” IHR-R39 was conducted in cooperation with the Illinois Center for Transportation, the Illinois Department of Transportation, and the U. S. Department of Transportation, Federal Highway Administration.

Technical Review Panel members Hal Wakefield (Federal Highway Administration), Scott Lackey, David Lippert, Rick Mauch, Matt Mueller, Paul Niedernhofer, Dave Piper, LaDonna Rowden, Jim Trepanier, Tom Winkelman, and Chairman Amy Schutzbach (all of the Illinois Department of Transportation) provided immeasurable assistance in the preparation and development of this report. Shannon Beranek provided the extensive dynamic modulus testing for this work and is to be commended for her tireless work.

The construction of these sections could not have been achieved without the on-site assistance of IDOT personnel, specifically Jim Trepanier, Laura Shanley, Tom Zehr, Joe Rechner, Tom Winkelman, and Amy Schutzbach from the Bureau of Materials and Physical Research, and the Region 3/District 5 Materials section.

The cooperation of Champaign Asphalt to construct these research pavements using very non-traditional construction procedures is greatly appreciated.

## DISCLAIMER

# EXTENDED LIFE HOT MIX ASPHALT PAVEMENT (ELHMAP) TEST SECTIONS AT ATREL

## CHAPTER 1 PROJECT BACKGROUND

Project IHR-R39, titled "Validation of Design Concepts for Extended Life Hot Mix Asphalt Pavements (ELHMAP)," was funded by the Illinois Department of Transportation (IDOT) to develop data in support of the philosophy of design and performance of the newly proposed concept of Perpetual Pavements (PP). The concept of a PP includes a rut resistant surface, a fatigue-resistant asphalt rich lower layer, and sufficient total thickness to eliminate the development of fatigue cracking. The IDOT vision of this concept consists of a rut-resistant surface layer, an intermediate layer of a typical IDOT mix, and a lower layer that may or may not need to be asphalt rich. The total thickness would produce a tensile strain at the bottom of the asphalt layers that would be below 70 micro strain during the hottest period of the year.

### 1.1 PROJECT OVERVIEW

The following description was developed for this research project:

> This research will provide test data for dynamic modulus and fatigue for current IDOT mixes in accordance with the Mechanistic Pavement Design Guide (MEPDG) from the American Association of State Highway and Transportation Officials (AASHTO) data requirements for pavement design. The fatigue testing will validate fatigue algorithms and illustrate the existence and magnitude of a fatigue endurance limit (FEL). Pavement sections will be selected by IDOT and constructed to demonstrate ELHMAP concepts as worked out by IDOT. Pavement sections for full scale testing will be scheduled for construction in Spring 2003.

To support the accomplishment of these general goals, the following work tasks were planned:

- Establish equipment for MEPDG testing
    - Dynamic modulus, E
    - Flexural fatigue
- Identify and collect IDOT mixtures for testing
- Conduct fatigue and dynamic modulus testing
- Examine temperature and structural characteristics for ELHMAP
- Establish thickness limitations
- Prepare Accelerated Transportation Loading ASsembly (ATLAS) work plan for construction and response testing
- Construct and conduct response testing of ATLAS sections
- Conduct testing of the ELHMAP thin fatigue section
- Establish mechanistic procedure for ELHMAP design

### 1.2 ACCELERATED TRANSPORTATION LOADING ASSEMBLY (ATLAS)

The University of Illinois owns and operates an accelerated pavement test device referred to as the Advanced Transportation Loading ASsembly (ATLAS). ATLAS is 124 feet long, 12 feet high, 12 feet wide, and weighs approximately 180 kips. ATLAS loads the pavement with a variable load level from 0 to 80 kips using a single tire, dual-wheel tire, or an aircraft tire. The loading on the pavement can be either unidirectional or bi-directional, and a 3-foot lateral wander can be programmed to simulate real traffic conditions. Other load variables include a 0 to 10 mph loading speed, a loading length of up to 85 feet, and a constant velocity loading of the wheel of up to 65 feet.

## 1.3 ELHMAP TEST SECTION GOALS

As outlined in the project goals, constructing ELHMAP cross sections is crucial to understand how these sections behave under load. The main purposes of the asphalt test sections were to:

- Validate the basic principles and concepts of IDOT's Mechanistic-Empirical (M-E) design procedure by combining laboratory modulus testing of mixtures used in construction with computer modeling to compare measured and predicted pavement response (tensile strain at bottom of asphalt layer) in a multi-layer, multi-material pavement system.
- Validate ELHMAP concepts by comparing performance and life of ELHMAP cross sections to standard IDOT full-depth HMA cross sections.
- Compare the laboratory fatigue algorithm to the performance of a trafficked field section to establish degree of difference, if any.
- Compare the effects of lime-modified subgrade versus aggregate subbase on the pavement response.

## 1.4 PROPOSED TEST SECTIONS

To accomplish the goals listed above, IDOT and the project team developed four pavement sections that include the basic ELHMAP principles and provide for trafficking. These pavement sections were constructed at the Advanced Transportation Research Laboratory (ATREL), located in Rantoul, Illinois, and are indicated as A, B, D, and F as shown in Figure 1. Figure 2 shows the cross sections for A, B, D, and F. Sections D and F were constructed over lime-modified subgrade. Sections A and B were replicated over both lime-modified subgrade and aggregate subbase.

Section A was a 16.5-inch section. The surface was 2 inches of stone matrix asphalt (SMA) over 4.5 inches of polymer-modified binder (PMB), over 6 inches of standard binder (SB), over 4 inches of rich bottom binder mix (RBB) (0.5 percent extra asphalt, compacted to 2-3 percent air voids).

Section B was a 16.5-inch section. The surface was 2 inches of dense graded surface (DGS) mix over 4.5 inches of PMB, over 10 inches of SB.

Section D was an intermediate 10-inch section with 2 inches of DGS over 4.5 inches of PMB mix, over 3.5 inches of SB mix.

Section F was a thin section used for fatigue testing to failure and was 2 inches of DGS mix over 4 inches of SB mix.

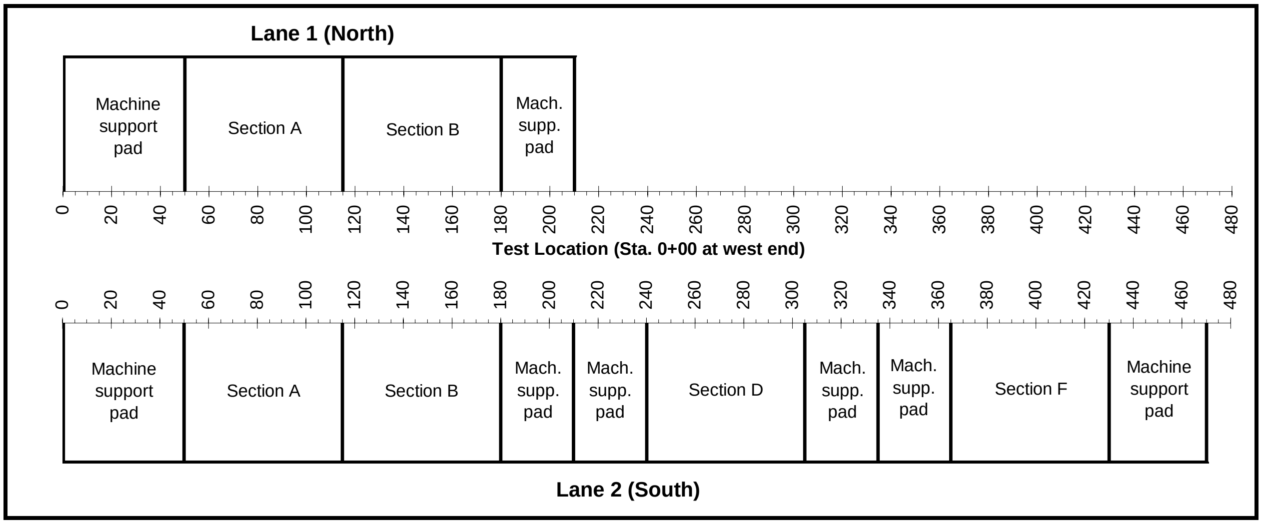



Figure 1. Project layout.

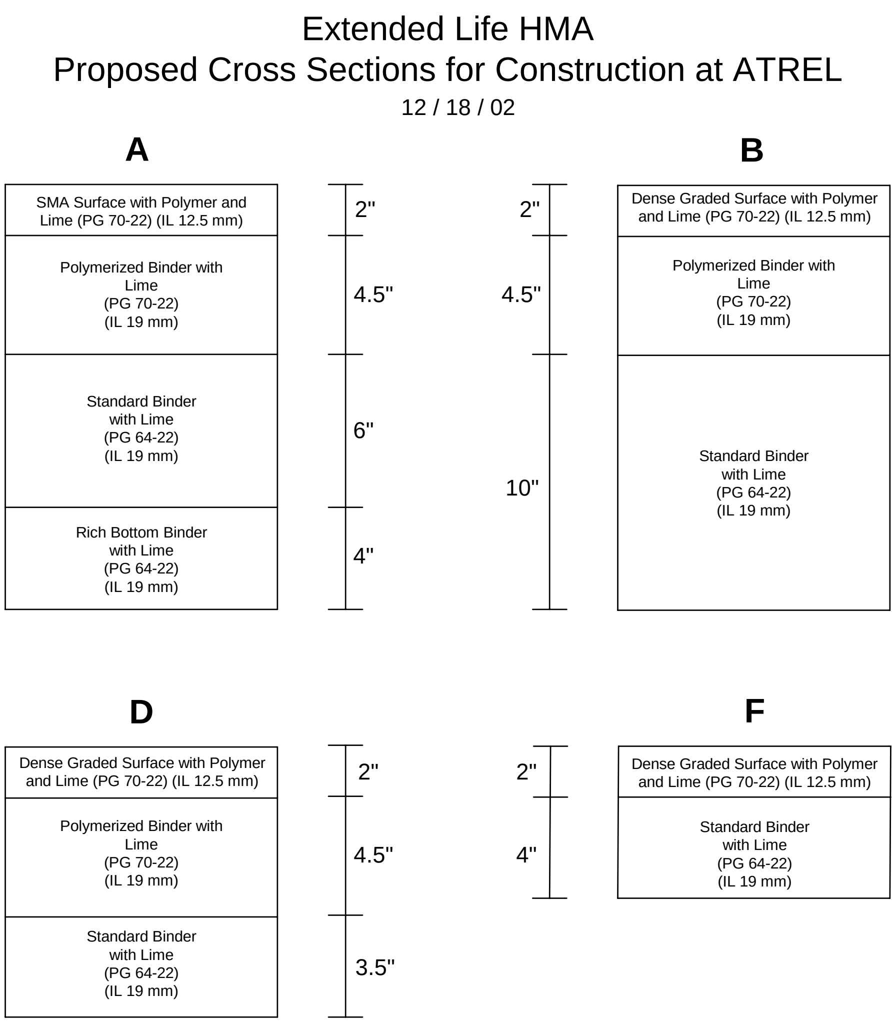



Figure 2. ELHMAP cross sections.

To produce these mixes in a timely manner with minimal cost for down time and startup, the Principal Investigators and IDOT personnel required that a batch plant be utilized for preparation of all but the SMA surface mixture.  Further, the lime added to the mixture had to be pug-mixed with the aggregate and stockpiled prior to mix preparation.

The vendor selected through a competitive bid process was Champaign Asphalt (CA):

Champaign Asphalt
1414 W Anthony Dr.
Urbana, IL

# CHAPTER 2 SUBGRADE CHARACTERIZATION

## 2.1 SITE LAYOUT AND SOIL CLASSIFICATION

Figure 3 shows the project site and layout for the ELHMAP sections at ATREL indicating the topography of the site and the relative location of the ELHMAP sections to the existing CRCP sections.

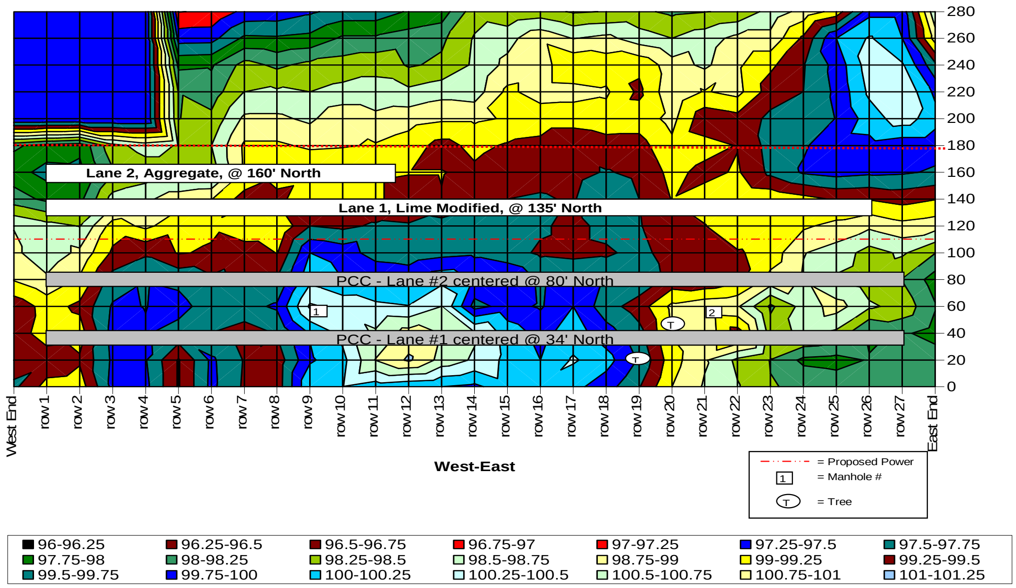



Figure 3. Topographic map of ELHMAP construction site.

The soil classification performed by District 5 OF IDOT is given in Figure 4. Sections A and B for both lanes classified as A-4 loam. Lane 2, Sections D and F (F is referred to in this figure as D(2)) classified as an A-6 and an A-2-6, respectively. This soil had a higher plastic limit than the A-4, with more clay content. This should produce a slightly lower support value for a pavement structure. Neither soil was significantly better than the other for pavement construction.

## Illinois Department of Transportation
## District 5 Soil Sample Results Summary

**Section:** U of I **Route:**

| | SAMPLE 1 | SAMPLE 2 | SAMPLE 3 | SAMPLE 4 | SAMPLE 5 |
|---|---|---|---|---|---|
| **Lab. No.:** | 1 | 2 | 3 | 4 | |
| **Station:** | S. Lane Section D(1) | S. Lane Section D(2) | N. Lane Section A/B | S. Lane Section A/B | |
| **Depth:** | N/A | N/A | N/A | N/A | |
| **HRB:** | A-6 | A-2-6 | A-4 | A-4 | |
| **GI:** | 10 | 1 | 2 | 2 | |
| **Grain Size Classification:** | SiCL | SL | LOAM | LOAM | |
| **Subgrade Support Rating:** | Poor | Poor | Poor | Poor | |
| | **GRADATION % PASSING** | | | | |
| **3/4" Sieve** | 100.00 | 100.00 | 100.00 | 100.00 | |
| **1/2" Sieve** | 100.00 | 100.00 | 100.00 | 100.00 | |
| **# 4 Sieve** | 100.00 | 99.15 | 91.27 | 90.50 | |
| **#10 Sieve** | 99.80 | 96.72 | 88.31 | 87.32 | |
| **# 40 Sieve** | 96.52 | 70.86 | 78.03 | 78.44 | |
| **# 100 Sieve** | 87.34 | 34.00 | 65.34 | 65.76 | |
| **# 200 Sieve** | 77.92 | 31.05 | 60.60 | 60.79 | |
| **% Sand** | 22.08 | 68.95 | 39.40 | 39.21 | |
| **% Silt** | 52.08 | 10.91 | 40.76 | 41.09 | |
| **% Clay** | 25.84 | 20.14 | 19.84 | 19.70 | |
| **Liquid Limit** | 31 | 31 | 23 | 25 | |
| **Plastic Limit** | 16 | 16 | 16 | 17 | |
| **Plastic Index** | 15 | 15 | 7 | 8 | |
| **Percent Silt & Fine Sand** | 70.68 | 50.72 | 58.19 | 58.75 | |
| **Std Dry Density** | 0 | 0 | 0 | 0 | |
| **Optimum Moisture** | 0.0% | 0.0% | 0.0% | 0.0% | |
| **Insutu % Moisture** | #N/A | #N/A | #N/A | #N/A | |
| **Insutu % of Optimum** | #N/A | #N/A | #N/A | #N/A | |
| **Organic Content** | | | | | |
| | **EMBANKMENT REQUIREMENTS** | | | | |
| **PI Greater Than 12%** | Pass | Pass | SEE NOTE 3 | SEE NOTE 3 | |
| **65%** | FAIL | Pass | Pass | Pass | |
| **Liquid Limit > 60%** | Pass | Pass | Pass | Pass | |
| **Organic Content > 10%** | Not Tested | Not Tested | Not Tested | Not Tested | |
| **Std Dry Density < 90%** | PROHIBITED | PROHIBITED | PROHIBITED | PROHIBITED | |
| **Clay Content < 20%** | Pass | Pass | See Note 1 | See Note 1 | |
| **Granular Soils (S & SL)** | N/A | SEE NOTE 2 | N/A | N/A | |
| **<60%** | Pass | Pass | Pass | Pass | |
| **Remarks** | | | | | |

**NOTE 1:** May NOT be used in the top 2' of embankment when subgrade will be lime modified.
**NOTE 2:** Embankment core only. Required cap thickness can vary and materials may be allowed in subgrade depending on design. May require drainage.
**NOTE 3:** Excluding Granular Soils: Embankment core only. Required cap thickness can vary depending on design.

U of I Soil Test

Figure 4. Soil analysis of ELHMAP test section locations.

## 2.2 MOISTURE-DENSITY OF SUBGRADE MATERIALS

Moisture-Density relationship tests were performed according to AASHTO T 99. The laboratory tests were conducted on representative samples of natural soil taken from Lane 1 Section A/B and Lane 2 Sections A/B and D/F. Laboratory tests were also conducted on representative samples of lime-modified soil (natural soil plus 5 percent lime) taken from Lane 2 Sections A/B, D, and F.

In addition, Immediate Bearing Values (IBV) on natural and lime-modified soil for the same lanes and sections were determined according to the IDOT Geotechnical Manual.

Tables 1 and 2 summarize the results obtained from the density and IBV testing for the natural and lime-modified soil, respectively. The soils under Sections D and F have a slightly lower density and higher moisture content as would be expected from the soil classification. The IBV's, considered as an analog to the California Bearing Ratio (CBR), are also lower for the soils under Sections D and F. The presence of increased clay under Sections D and F is shown in the strength improvement produced by the lime-modification. The IBV for Sections D and F almost doubles with the lime treatment, a good indicator of the presence of higher amounts of clay under these sections.

Table 1. OMC, Maximum Dry Density, and IBV for the Natural Soil

| Lane 1 | | | | | | Lane 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Section | Location | | OMC | D.Density | IBV | Section | Location | | OMC | D.Density | IBV |
| | From | To | (%) | (pcf) | @ OMC | | From | To | (%) | (pcf) | @ OMC |
| A/B | 50 | 180 | 11.2 | 125.4 | 25.0 | A/B | 50 | 180 | 11.1 | 126.2 | 30.5 |
| | | | | | | D/F | 240 | 430 | 13.1 | 119.1 | 24.3 |

Table 2. OMC, Maximum Dry Density, and IBV for the Lime-Modified Soil

| Lane 2 | | | | | |
|---|---|---|---|---|---|
| Section | Location | | OMC | D.Density | IBV |
| | From | To | (%) | (pcf) | @ OMC |
| A/B | 50 | 180 | 14.6 | 118.8 | 24.3 |
| D | 240 | 305 | 14.7 | 117.2 | 42.0 |
| F | 365 | 430 | 17.7 | 109.3 | 38.0 |

**2.3 UNCONFINED COMPRESSIVE STRENGTH (Qu)**

Samples of soil were prepared in 4-inch high by 2-inch diameter molds with the samples of natural and lime-modified soil taken from Lane 1 and 2, producing three replicates per soil sample.

The specimens were compacted in the molds in three layers (20 blows, 4-pound hammer falling 12 inches). Following compaction, the samples were extruded from the molds and wrapped in plastic to maintain moisture content. The samples were cured at room temperature. Natural soil specimens were cured for seven days (to allow for thixotropic effects), and the lime-modified specimens were cured for 28 days.

After the curing period, the specimens were tested in unconfined compression at a rate of deformation of 0.05 inches per minute. The average of the maximum load of the three specimens per sample was presented as the unconfined compressive strength (Qu). The moisture content at the time of the test and the dry density of the specimens were also determined.

Tables 3 and 4 summarize the average Qu, moisture content, and dry density for the specimens prepared with natural soil and lime-modified soil respectively. The compressive strengths illustrate the same trend as shown by the IBV test. The dramatic increases in the unconfined compressive strength resulting from the lime-modification clearly indicate the effectiveness of lime-modification for these soils.

Table 3. Qu, Moisture Content, and Dry Density for the Natural Soil

| Lane 1 | | | | | | Lane 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Section | Location From | Location To | Qu (psi) | Moisture Content (%) | Dry Density (pcf) | Section | Location From | Location To | Qu (psi) | Moisture Content (%) | Dry Density (pcf) |
| A/B | 50 | 180 | 81.5 | 10.4 | 124.2 | A/B | 50 | 180 | 71.0 | 10.2 | 122.0 |
| | | | | | | D/F | 240 | 430 | 65.1 | 12.9 | 119.0 |

Table 4. Qu, Moisture Content, and Dry Density for the Lime-Modified Soil

| Lane 2 | | | | | |
|---|---|---|---|---|---|
| Section | Location From | Location To | Qu (psi) | Moisture Content (%) | Dry Density (pcf) |
| A/B | 50 | 180 | 134.3 | 13.4 | 110.8 |
| D | 240 | 305 | 135.7 | 13.6 | 109.9 |
| F | 365 | 430 | 131.1 | 16.0 | 102.6 |

# CHAPTER 3 SITE PREPARATION

### 3.1 TOPSOIL REMOVAL

Site preparation consisted of stripping the topsoil to a consistent depth that would allow the lime-modified subgrade and the aggregate subbase to be at the same final elevation prior to final asphalt paving. The site stripped of top soil is shown in Figure 5.

Figure 5. Lanes with topsoil removed.

### 3.2 LIME-MODIFICATION

Following the stripping activity, Lane 1 (the South lane) was modified with lime. Approximately 2 - 3 percent lime was added, and moisture was added to maintain optimum moisture content during compaction and curing. Figure 6 presents the construction sequence for the lime modification process. The lime was spread with a spreader and mixed with a Bomag pulvimixer to a depth of approximately 12 inches.

Figure 6.  Construction of the lime-modified lane.

### 3.3 AGGREGATE SUBBASE

Lane 2, the North lane, received a compacted aggregate subbase approximately 12 inches thick. During the top soil stripping process, an extremely weak silt layer was encountered in this lane. This soft material was removed and backfilled with aggregate. The undercutting at this location is shown in Figure 7. This location is under a machine support pad, and not in a testing section. The aggregate construction is shown in Figure 8. Following construction of the aggregate subbase, one location was noted where the underlying subgrade had been pumped through the aggregate during compaction, leaving unstable spots. This location was removed, extra aggregate added, and the location was re-compacted, as shown in Figure 9.

Figure 7. Undercutting at soft spot in Lane 1, aggregate lane.

Figure 8. Construction of the aggregate lane.

Figure 9.  Excavation and replacement of soft grade and contaminated aggregate.

**3.4 AGGREGATE DENSITY**

Following completion of the aggregate subbase, the density was checked using an approved nuclear density gauge by ERI, an engineering testing firm in Savoy, Illinois.  Table 5 gives the density data, indicating that the density is satisfactory for a CA-6 even though an ELHMAP pavement structure has no density requirement for the aggregate subbase. Location 1 was in the reconstructed aggregate section, as shown in Figure 10.

Figure 10.  Nuclear density test on reconstructed aggregate subbase.

Table 5.  Nuclear Density Tests for Aggregate Subbase

| **Test Location** | **1** | **2** | **3** |
|---|---|---|---|
| **Density, (pcf)** | 142.2 | 129.7 | 143.6 |

## 3.5 FALLING WEIGHT DEFLECTOMETER (FWD) TESTING

Falling weight deflectometer (FWD) testing of the aggregate subbase (Lane 1, Sections A and B) and lime-modified subgrade (Lane 2, Sections A, B, D, and F) was performed following construction and a one-week curing period.

The deflections at the center of the plate (D0) were normalized to a 6000-lb load, the standard load used on a grade, and the Boussinesq elastic half space equation for rigid plate was applied:

$$E = \frac{(\pi/2)\cdot p\cdot r\cdot(1-\nu^2)}{\Delta} \qquad (1)$$

where:

E = Composite Modulus (psi)
p = Applied Contact Pressure (psi)
r = Plate Radius (5.9 inches)
$\nu$ = Poisson's Ratio (0.5)
$\Delta$ = Deflection (inch)

Figure 11 shows the profiles of the modulus obtained in both lanes.  The mean modulus of the aggregate subbase and the coefficient of variation (COV) are given in Table 6 for each section in Lane 1.  Table 7 shows the mean modulus and COV of the lime-modified subgrade obtained for each section in Lane 2.  The COV is the mean divided by the standard deviation, expressed as a percent.

The COV is much lower for the aggregate subbase, indicative of the prepared nature of the compacted aggregate.  The composite moduli of the lime-modified lane are significantly higher than the aggregate lane, indicating the impact of lime-modification on soils with high clay content relative to aggregate subbase.  The COV of the lime-modified sections is more typical of what is found in naturally occurring soils.

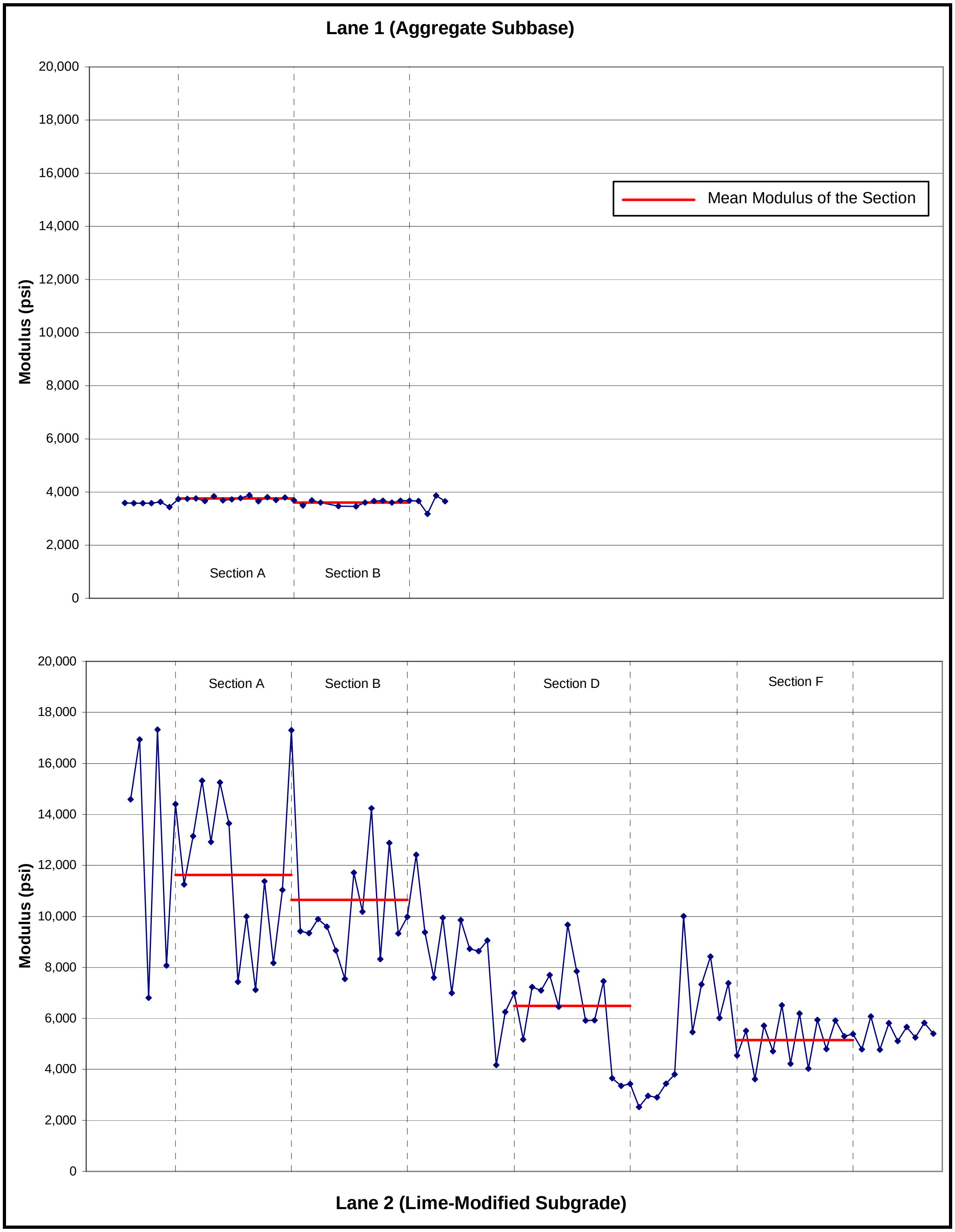



Figure 11. Modulus profiles from FWD testing on finished grade.

Table 6. Aggregate Subbase Modulus (Lane 1)

| Section | Location From / To | Modulus Mean (psi) | Modulus Stdev (psi) | Modulus COV (%) |
|---|---|---|---|---|
| A | 50 / 115 | 3,754 | 69 | 1.8 |
| B | 115 / 180 | 3,601 | 89 | 2.5 |

Table 7. Lime-Modified Subgrade Modulus (Lane 2)

| Section | Location From / To | Modulus Mean (psi) | Modulus Stdev (psi) | Modulus COV (%) |
|---|---|---|---|---|
| A | 50 / 115 | 11,621 | 2,823 | 24.3 |
| B | 115 / 180 | 10,649 | 2,725 | 25.6 |
| D | 240 / 305 | 6,496 | 1,728 | 26.6 |
| F | 365 / 430 | 5,152 | 903 | 17.5 |

### 3.6 DCP TESTING

Following construction of the aggregate subbase and lime-modified subgrade, 24 Dynamic Cone Penetrometer (DCP) tests were performed using the automatic trailer mounted equipment (ADCP) maintained at ATREL. Nine tests were conducted on the aggregate subbase, and 15 tests were conducted on the lime-modified subgrade.

Penetration rates in each test were used to obtain CBR values at different depths using equation 2:

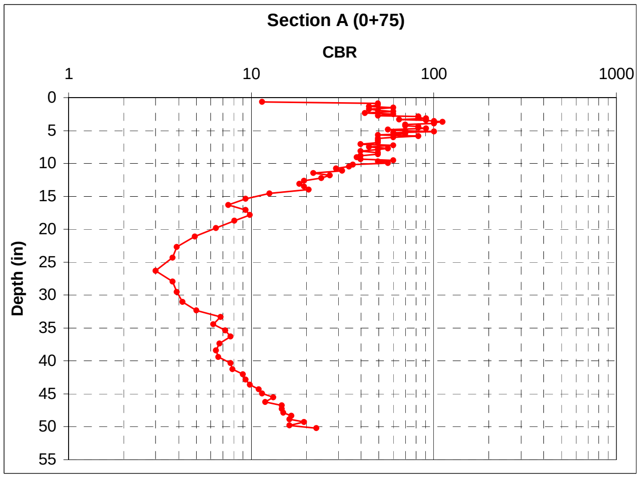
$$\log(CBR) = 0.84 - 1.26 \cdot \log(PR) \tag{2}$$

where:

CBR = California Bearing Ratio, (interchangeable with IBV)
PR = ADCP penetration rate (inch/blow)

Although, as mentioned earlier, 24 ADCP tests were performed, herein only one test per section is presented as representative of the section data.

Figures 12 and 13 present the values of CBR as a function of depth in Lane 1 (aggregate subbase) Sections A and B, respectively. Figures 14, 15, 16, and 17 present the results of Lane 2 (lime-modified subgrade) Sections A, B, D, and F, respectively.



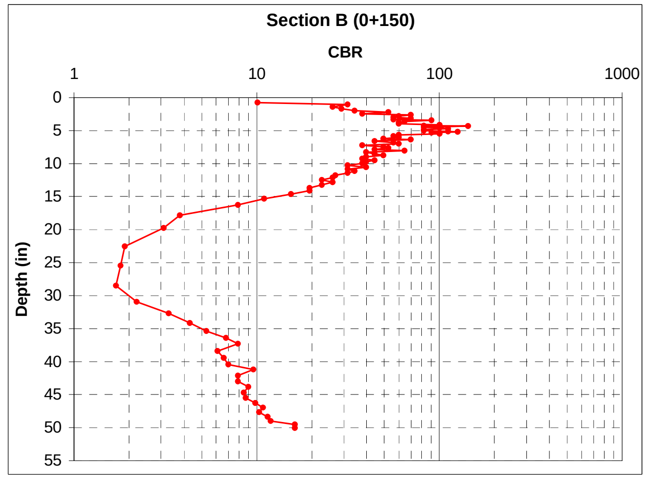
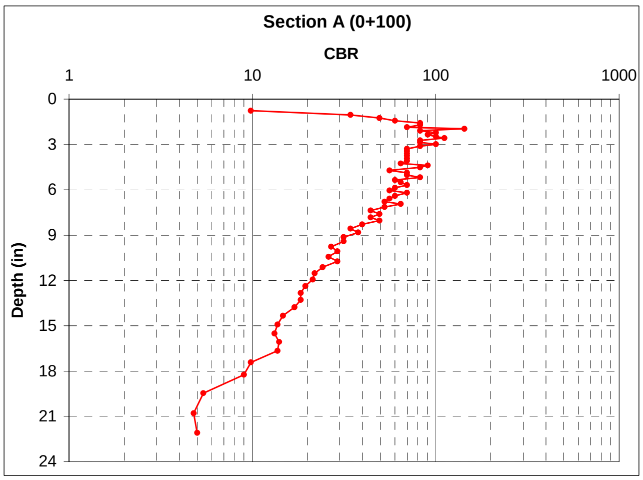




Figure 12. CBR, Lane 1, Section A.

Figure 13. CBR, Lane 1, Section B.



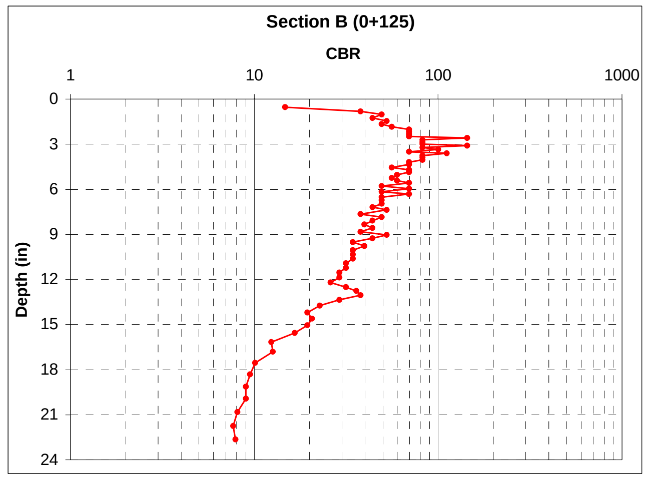
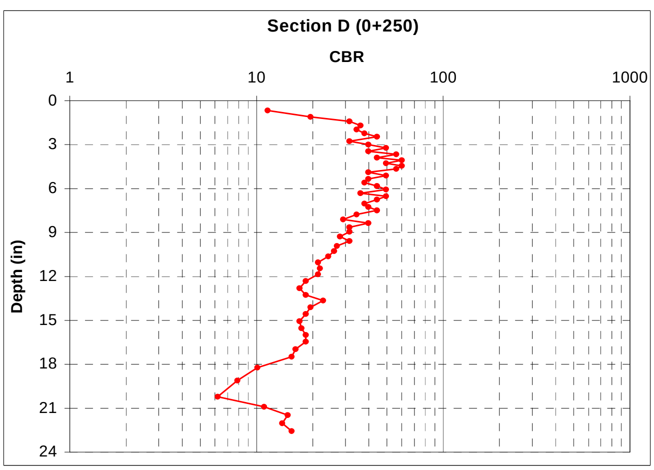




Figure 14. CBR, Lane2, Section A.

Figure 15. CBR, Lane 2, Section B.



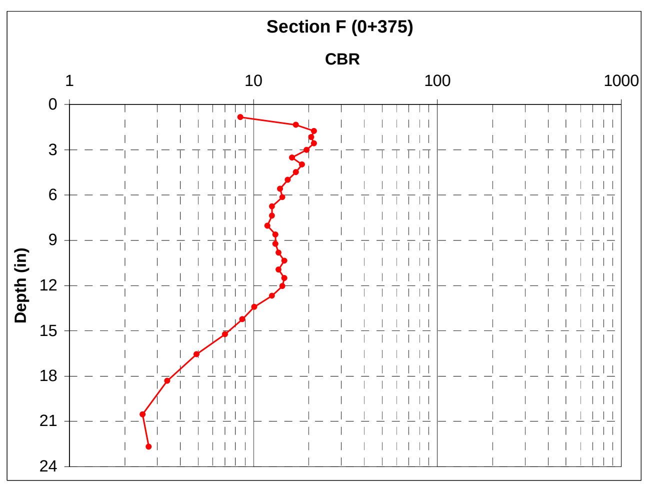




Figure 16. CBR, Lane 2, Section D.

Figure 17. CBR, Lane 2, Section F.

These plots of CBR with depth clearly show the differences between the two construction procedures. Lane 1 shows the aggregate subbase with high CBR over low CBR natural grade with a relatively distinct break between the two materials. Lane 2, Sections A and B show a similar trend with the lime modified subgrade having high CBR values and being underlain with lower CBR natural soil below the 12-inch depth. Sections D and F do not show the same high CBR in the lime-modified soil, which could be the result of a construction sequence (inadequate mixing, insufficient water, inadequate lime addition). These soils clearly demonstrated a significant strength increase with the addition of lime under laboratory conditions. This trend in lower field strengths is also seen in the modulus plots (see Figure 11), which show Sections D and F having lower modulus values.

### 3.7 POST CONSTRUCTION STORM

Following construction of the aggregate subbase and lime-modified subgrade, but prior to the FWD and ADCP testing program, Rantoul experienced a severe thunderstorm which put both lanes under water, as shown in Figure 18. This ponding of water is typical of the drainage characteristics of these natural soils in Illinois. The site was dewatered with portable sump pumps the morning after the rain, as shown in Figure 19. No adverse effects were observed from this short-term submergence of the grades, and the test data certainly indicate no strength loss due to the soaking activity.

Figure 18. Project site following rain storm.


Figure 19.  Project site following dewatering.

# CHAPTER 4 INSTRUMENTATION

## 4.1 GAUGES

Two basic types of instrumentation were installed within the ELHMAP test sections to appropriately analyze their structure. Strain gauges are required to measure the tensile bending strain at the bottom of the asphalt layers. This measurement is used as the main structural response design value for thickness determination. Thermocouples are required at various depths to generate temperature profiles. The temperature profile is necessary to adjust the modulus of the HMA with temperature variations at various depths and for seasonal adjustments.

The Dynatest strain gauges are the long-term environmental models (PAST – II AC) shown in Figure 20. The type-T thermocouples are copper-constantan, shown in Figure 21.

Figure 20. Dynatest strain gauge.

Figure 21. Thermocouples.

## 4.2 STRAIN GAUGE PLACEMENT

After completing subgrade preparation for the lime-modified subgrade and the aggregate subbase, three strain gauges were placed along the centerline of each test section in the approximate center of the section. Two of the gauges were placed laterally, and the third was placed longitudinally as shown in Figure 22. These gauges were first seated in a thin layer of polymer modified mix that was scalped to produce a sand size mix. These gauges were then covered using a thin layer of an asphalt sand mixture to keep the gauges in place during the initial stages of paving.

Figure 22. Placement of strain gauges.

The reason for using an asphalt sand mixture was to ensure that no large aggregates would be in direct contact with the strain gauge, which would prevent possible breakage of the gauge. The wires of the strain gauges were embedded into a small hand-made trench in the top layer of the subgrade and held in place by metal "u-shaped" fasteners to ensure that the wires did not get caught on the paving machine during the initial stages of paving. This initial preparation provided a cool HMA cover to the gauges that prevented movements when fresh HMA was placed and the paving equipment passed for placement and compaction. The strain gauges were checked after construction, and all gauges were functioning.

## 4.3 THERMOCOUPLE PLACEMENT

Concurrent with placement of the strain gauges following subgrade preparation, a single thermocouple wire was placed on top of the subgrade and held in place using the asphalt sand mixture. This thermocouple was placed near the strain gauges. The end of the thermocouple wire leading out to the edge of the pavement section was buried with the strain gauge wires and held in place by the metal fasteners.

Upon completion of the HMA paving, additional thermocouples were added to provide temperature measurements at specific depths in the HMA structure. To accomplish this, a 2-inch diameter core was taken adjacent to the initial thermocouple location. Depending on the thickness of the test section, a different number of thermocouples were placed at specific depths. The bore-hole was backfilled with the sand mix after each thermocouple was placed. The thermocouple was placed on the layer of compacted sand mix, at the specified depth, and then the hole was filled to the next level. The respective depths of the complete thermocouple installations are shown in Table 8.

Table 8. Thermocouple Depths (inches) in Each Section

| Lane | Section A | Section B | Section D | Section F |
|---|---|---|---|---|
| **Aggregate** | 16.5, 13, 8, 4, 1 | 16.5(2), 12, 8, 4, 1 | | |
| **Lime Modified** | 16.5(2), 12, 8, 4, 1 | 16.5(2), 12, 8, 4, 1 | 10, 8.5, 6, 3, 1 | 6(2), 3, 1 |

# CHAPTER 5 HMA CONSTRUCTION

## 5.1 EQUIPMENT

In an attempt to eliminate segregation and mixture variations and prevent aggregate subbase/lime-modified subgrade disturbance from repeated paving operations, a Material Transfer Device (MTD) was specified for these short sections. To accommodate the MTD, the center area between the two pavements was topped with a layer of recycled asphalt pavement (RAP). This RAP material was donated by the city of Rantoul. From this central area, the MTD could directly supply the paver with HMA on either lane. Figure 23 illustrates the RAP center area with the MTD in operation.

Figure 23. MTD on RAP center lane during paving.

Additional construction equipment in the paving sequence included the paver, a vibratory roller, and a finish roller. The paver and finish roller are shown in Figure 24.


Figure 24. Paver and finish roller.

## 5.2 HMA MIXTURES

The layered construction of these sections required different mixtures. The different mixture types, their abbreviations in parenthesis, number of gyrations, and mix design numbers include:

- Rich Bottom Base (RBB), N90, 85 BIT 1114
- Standard Binder Mix (SB), N90, 85 BIT 1112
- Polymer Modified Binder Mix (PMB), N90, 85 BIT 1111
- Dense-Graded Surface Mix (DGS), N90, 85 BIT 1113
- Stone Matrix Asphalt Mix (SMA), N80, 85 BIT 3890

With the exception of the SMA mixture, all mixtures were produced at the batch plant in Champaign, Illinois. The SMA mixture was hauled from the plant at Marshall, Illinois. This plant was producing this mix for a project on I-70 at the time, and the SMA mixture obtained was the same mixture being placed on the I-70 project. This longer haul distance necessitated higher temperatures for the SMA which was both polymer and fiber modified. All mixtures used in the ELHMAP sections except for the SMA had lime introduced into the aggregate as a slurry during production of the aggregate stockpiles. For the SMA mixture, the lime was introduced dry, as a mineral filler.

The mix design information is shown in Figures 25 through 29.

## 5.3 CONSTRUCTION SEQUENCE

The HMA was constructed in three days from May 29 through June 2, 2003. The nature of the short sections and the different variety of mixtures used required a well coordinated effort between the field and plant to accommodate the start and stop nature of the paving and the mixture changes necessary to construct the individual lifts and get them compacted and cooled before another lift was placed over the previous lift.

Figure 30 is a schematic cross section of the two pavement lanes. Individual lifts are shown, and each day's paving is shown in a continuous type of shading. The text within each lift includes the following, in order of use:

- Paving sequence number
- Lane/lift indicator (Lane, Section, Lift)
- Mix abbreviation
- Placement date
- Approximate paving time

There were 30 distinct paving operations, some of which involved continuous placement of a particular mix over several sections, and most of which required either equipment moving to different sections or different mixtures being placed.

| | |
|---|---|
| MIX TYPE: | Bituminous Concrete Binder Course (PMB), N90, Illinois 19.0, (Polymerized) |
| MIX NUMBER: | 85 BIT 1111 |
| ASPHALT CEMENT GRADE | SBS PG 70-22 |
| MAXIMUM SPECIFIC GRAVITY (Gmm) | 2.477 |
| BULK SPECIFIC GRAVITY (Gmb) | 2.379 |
| PERCENT VOIDS | 4.0 |

MATERIAL SOURCES

| | | | |
|---|---|---|---|
| Coarse Aggregate | 042CMM11 | Material Service, Fairmont, IL | 39.9 % |
| Coarse Aggregate | 032CMM16 | Material Service, Fairmont, IL | 34.2 % |
| Fine Aggregate | 038FAM20 | Material Service, Fairmont, IL | 24.9 % |
| Lime | 003FAM00 | Mississippi Lime Co., St. Genevieve, MO | 1.0 % |
| Asphalt Cement | | Emulsicoat, Urbana, IL | 4.5 % |

| Aggregate Gradations | | | | | |
|---|---|---|---|---|---|
| | 042CMM11 | 032CMM16 | 038FAM20 | 003FAM00 | Blend |
| Type | Limestone | Limestone | Limestone | Lime | N/A |
| Quality | Class C | Class B | Class B | N/A | N/A |
| Sieve Size | | | | | |
| 25.4 | 100 | 100 | 100 | 100 | 100 |
| 19.9 | 95.1 | 100 | 100 | 100 | 98.4 |
| 12.5 | 38.2 | 100 | 100 | 100 | 75.3 |
| 9.5 | 13.4 | 97.8 | 100 | 100 | 64.7 |
| 4.75 | 3.2 | 33.8 | 98.7 | 100 | 38.4 |
| 2.36 | 2.2 | 6.5 | 72.4 | 100 | 21.5 |
| 1.18 | 1.9 | 3.5 | 40.5 | 100 | 13.0 |
| 600μm | 1.7 | 3.0 | 23.0 | 100 | 8.4 |
| 300 μm | 1.6 | 2.7 | 13.2 | 100 | 6.8 |
| 150 μm | 1.5 | 2.5 | 7.9 | 99.0 | 4.4 |
| 75 μm | 1.3 | 2.3 | 6.8 | 97.0 | 3.7 |

No liquid anti-strips were used in this mixture.

Figure 25.  Mix design, polymer modified binder course (PMB).

| | |
|---|---|
| MIX TYPE: | Bituminous Concrete Binder Course (SB), N90, Illinois 19.0, (Standard) |
| MIX NUMBER: | 85 BIT 1112 |
| ASPHALT CEMENT GRADE | PG 64-22 |
| MAXIMUM SPECIFIC GRAVITY (Gmm) | 2.477 |
| BULK SPECIFIC GRAVITY (Gmb) | 2.377 |
| PERCENT VOIDS | 4.0 |

MATERIAL SOURCES

| | | | |
|---|---|---|---|
| Coarse Aggregate | 042CMM11 | Material Service, Fairmont, IL | 40.5 % |
| Coarse Aggregate | 032CMM16 | Material Service, Fairmont, IL | 33.0 % |
| Fine Aggregate | 038FAM20 | Material Service, Fairmont, IL | 25.5 % |
| Lime | 003FAM00 | Mississippi Lime Co., St. Genevieve, MO | 1.0 % |
| Asphalt Cement | | Emulsicoat, Urbana, IL | 4.5 % |

| Aggregate Gradations | | | | | |
|---|---|---|---|---|---|
| | 042CMM11 | 032CMM16 | 038FAM20 | 003FAM00 | Blend |
| Type | Limestone | Limestone | Limestone | Lime | N/A |
| Quality | Class C | Class B | Class B | N/A | N/A |
| Sieve Size | | | | | |
| 25.4 | 100 | 100 | 100 | 100 | 100 |
| 19.9 | 96.1 | 100 | 100 | 100 | 98.4 |
| 12.5 | 38.2 | 100 | 100 | 100 | 75.0 |
| 9.5 | 13.4 | 97.9 | 100 | 100 | 64.2 |
| 4.75 | 3.2 | 33.8 | 98.7 | 100 | 38.8 |
| 2.36 | 2.2 | 5.5 | 72.4 | 100 | 22.2 |
| 1.18 | 1.9 | 3.5 | 40.5 | 100 | 13.3 |
| 600 μm | 1.7 | 3.0 | 23.0 | 100 | 6.5 |
| 300 μm | 1.6 | 2.7 | 13.2 | 100 | 5.9 |
| 150 μm | 1.6 | 2.5 | 7.9 | 99.0 | 4.4 |
| 75 μm | 1.3 | 2.3 | 5.9 | 97.0 | 3.8 |

No liquid anti-strips were used in this mixture.

Figure 26. Mix design, standard binder course (SB).

| | |
|---|---|
| MIX TYPE: | Bituminous Concrete Surface Course (DGS), N90, Illinois D mix, (Dense Graded) |
| MIX NUMBER: | 85 BIT 1113 |
| ASPHALT CEMENT GRADE | SBS PG 70-22 |
| MAXIMUM SPECIFIC GRAVITY (Gmm) | 2.443 |
| BULK SPECIFIC GRAVITY (Gmb) | 2.343 |
| PERCENT VOIDS | 4.0 |

MATERIAL SOURCES

| | | | |
|---|---|---|---|
| Coarse Aggregate | 032CMM16 | Material Service, Fairmont, IL | 31.5 % |
| Coarse Aggregate | 031CMM16 | Carrie Scharf Material Co., Funks Grove, IL | 30.5 % |
| Fine Aggregate | 009FAM20 | Carrie Scharf Material Co., Funks Grove, IL | 20.0 % |
| Fine Aggregate | 031FAM01 | Carrie Scharf Material Co., Funks Grove, IL | 14.7 % |
| Mineral Filler | 004MFM01 | Bloomington Creek Stone, Bloomington, IN | 2.3 % |
| Lime | 003FAM00 | Mississippi Lime Co., St. Genevieve, MO | 1.0 % |
| Asphalt Cement | | Emulsicoat, Urbana, IL | 5.4% |

| Aggregate Gradations | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 032CMM16 | 031CMM16 | 009FAM20 | 031FAM01 | 004MFM01 | 003FAM00 | Blend |
| Type | Limestone | Gravel | Gravel | Gravel | Min. Filler | Lime | N/A |
| Quality | Class B | Class B | N/A | Class B | N/A | N/A | N/A |
| Sieve Size | | | | | | | |
| 25.4 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 19.9 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 12.5 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 9.5 | 97.0 | 93.2 | 100 | 100 | 100 | 100 | 97.0 |
| 4.75 | 33.5 | 30.2 | 93.1 | 99.6 | 100 | 100 | 57.3 |
| 2.36 | 5.8 | 3.9 | 76.6 | 87.6 | 100 | 100 | 34.3 |
| 1.18 | 3.6 | 1.1 | 48.3 | 56.6 | 100 | 100 | 22.7 |
| 600 μm | 2.8 | 0.8 | 31.0 | 29.5 | 100 | 100 | 15.0 |
| 300 μm | 2.6 | 0.7 | 19.0 | 5.4 | 100 | 100 | 8.9 |
| 150 μm | 2.4 | 0.6 | 10.4 | 1.0 | 95.0 | 99.0 | 6.3 |
| 75 μm | 2.3 | 0.5 | 5.9 | 0.7 | 85.0 | 97.0 | 6.1 |

No liquid anti-strips were used in this mixture.

Figure 27. Mix design, dense graded surface course (DGS).

| | |
|---|---|
| MIX TYPE: | Bituminous Concrete Binder Course (RBB), N90, Illinois 19.0, (Rich Bottom Binder) |
| MIX NUMBER: | 85 BIT 1114 |
| ASPHALT CEMENT GRADE | PG 64-22 |
| MAXIMUM SPECIFIC GRAVITY (Gmm) | 2.457 |
| BULK SPECIFIC GRAVITY (Gmb) | 2.393 |
| PERCENT VOIDS | 2.5 |

MATERIAL SOURCES

| | | | |
|---|---|---|---|
| Coarse Aggregate | 042CMM11 | Material Service, Fairmont, IL | 40.5 % |
| Coarse Aggregate | 032CMM16 | Material Service, Fairmont, IL | 33.0 % |
| Fine Aggregate | 038FAM20 | Material Service, Fairmont, IL | 25.5 % |
| Lime | 003FAM00 | Mississippi Lime Co., St. Genevieve, MO | 1.0 % |
| Asphalt Cement | | Emulsicoat, Urbana, IL | 5.1 % |

| Aggregate Gradations | | | | | |
|---|---|---|---|---|---|
| | 042CMM11 | 032CMM16 | 038FAM20 | 003FAM00 | Blend |
| Type | Limestone | Limestone | Limestone | Lime | N/A |
| Quality | Class C | Class B | Class B | N/A | N/A |
| Sieve Size | | | | | |
| 25.4 | 100 | 100 | 100 | 100 | 100 |
| 19.9 | 96.1 | 100 | 100 | 100 | 98.4 |
| 12.5 | 38.2 | 100 | 100 | 100 | 75.0 |
| 9.5 | 13.4 | 97.9 | 100 | 100 | 64.2 |
| 4.75 | 3.2 | 33.8 | 96.7 | 100 | 38.6 |
| 2.36 | 2.2 | 5.5 | 72.4 | 100 | 22.2 |
| 1.18 | 1.9 | 3.5 | 40.5 | 100 | 13.3 |
| 600 μm | 1.7 | 3.0 | 23.0 | 100 | 8.5 |
| 300 μm | 1.6 | 2.7 | 13.2 | 100 | 6.9 |
| 150 μm | 1.5 | 2.5 | 7.9 | 100 | 4.4 |
| 75 μm | 1.3 | 2.3 | 5.9 | 100 | 3.8 |

No liquid anti-strips were used in this mixture.

Figure 28. Mix design, rich bottom binder mixture (RBB).

| | |
|---|---|
| MIX TYPE: | Stone Matrix Asphalt Surface Course (SMA), N80 |
| MIX NUMBER: | 85 BIT 3809 |
| ASPHALT CEMENT GRADE | SBS PG 76-28 |
| MAXIMUM SPECIFIC GRAVITY (Gmm) | 2.937 |
| BULK SPECIFIC GRAVITY (Gmb) | 2.619 |
| PERCENT VOIDS | 4.0 |

MATERIAL SOURCES

| | | | |
|---|---|---|---|
| Coarse Aggregate | 039CMM11 | Heritage Slag, Gary, IN | 11.6 % |
| Coarse Aggregate | 039CMM13 | Heritage Slag, Gary, IN | 74.8 % |
| Fine Aggregate | 038FAM20 | Quality Lime Company, Marshall, IL | 8.0 % |
| Mineral Filler | 004MFM01 | Material Service, Nokomis, IL | 4.6 % |
| Lime | 003FAM00 | Mississippi Lime Co., St. Genevieve, MO | 1.0 % |
| Asphalt Cement | | Emulsicoat, Urbana, IL | 5.4 % |

| Aggregate Gradations | | | | | | |
|---|---|---|---|---|---|---|
| | 039CMM11 | 039CMM13 | 038FAM20 | 004MFM01 | 003FAM00 | Blend |
| Type | Steel Slag | Steel Slag | Limestone | Min. Filler | Lime | N/A |
| Quality | Class B | Class B | Class B | N/A | N/A | N/A |
| Sieve Size | | | | | | |
| 25.4 | 100 | 100 | 100 | 100 | 100 | 100 |
| 19.9 | 100 | 100 | 100 | 100 | 100 | 100 |
| 12.5 | 34.3 | 100 | 100 | 100 | 100 | 92.4 |
| 9.5 | 7.4 | 63.6 | 100 | 100 | 100 | 77.0 |
| 4.75 | 2.6 | 21.8 | 99.4 | 100 | 100 | 30.1 |
| 2.36 | 2.2 | 9.1 | 72.9 | 100 | 100 | 18.6 |
| 1.18 | 2.1 | 7.1 | 37.9 | 100 | 100 | 14.2 |
| 600 µm | 2.0 | 6.4 | 22.5 | 100 | 100 | 12.4 |
| 300 µm | 1.9 | 5.4 | 14.0 | 100 | 100 | 11.0 |
| 150 µm | 1.6 | 4.3 | 9.3 | 95.0 | 99.0 | 9.5 |
| 75 µm | 1.4 | 2.9 | 6.9 | 85.0 | 97.0 | 7.8 |

No liquid anti-strips were used in this mixture.
ATREL MIXTURE DESIGNS.DOC

Figure 29. Mix design, SMA surface course (SMA).

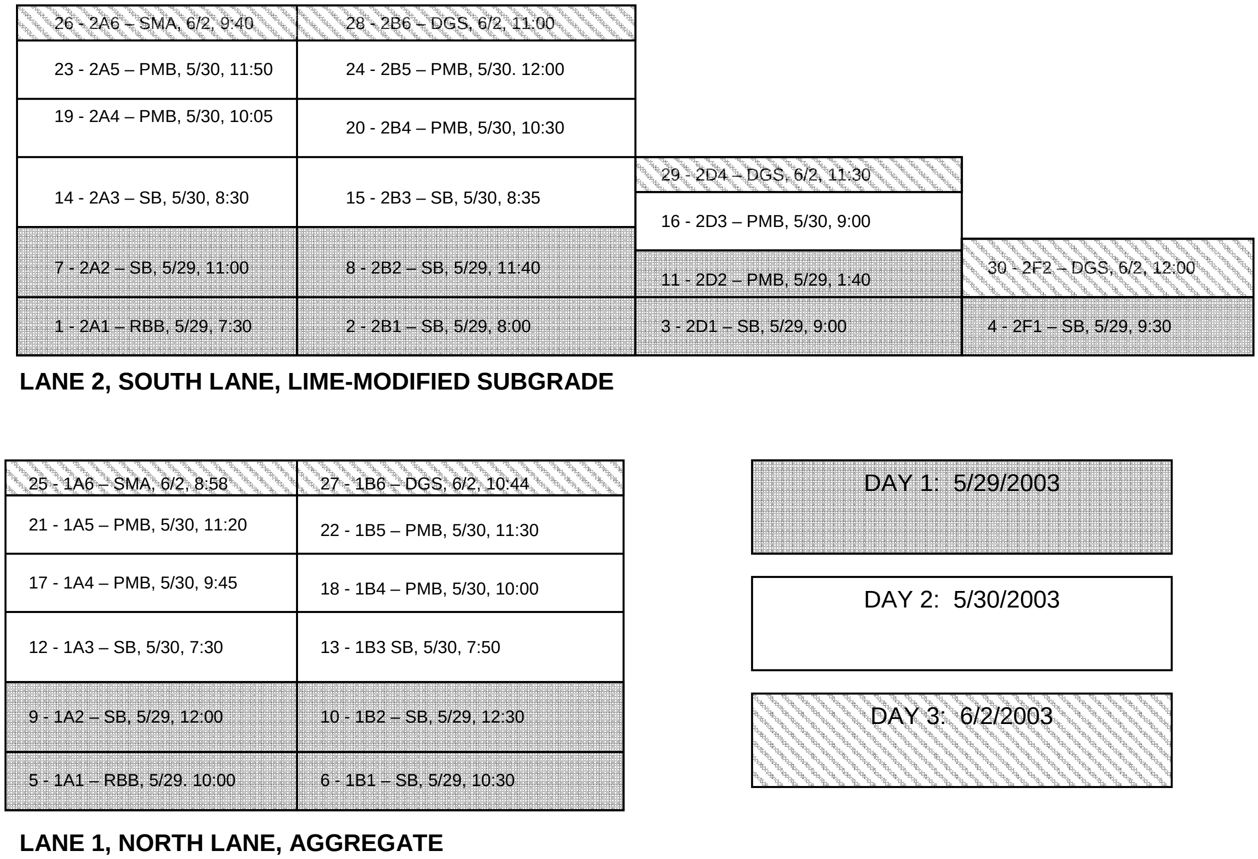



Figure 30. Construction sequencing for HMA paving operations.

### 5.3.1 May 29

Paving started on May 29, 2003, placing the first lift of RBB and SB on Lane 1 and Lane 2. RBB was placed on Lane 2, Section A. The mix was changed to the SB, and paving continued on Lane 2, completing Sections B, D, and F. The equipment moved to Lane 1, and the mix was changed to the RBB to pave Section A. Paving continued with a mix change to the SB to complete Section B. The equipment moved to Lane 2, and SB was placed for lift 2 on Sections A and B. The equipment moved to Lane 1, and continued placing SB as lift 2 on Sections A and B. The final paving operation involved moving equipment to Lane 2 and placing the PMB for lift 2, Section D.

### 5.3.2 May 30

Paving began on May 30, 2003, with the placement of SB on Lane 1, lift 3, Sections A and B. The equipment then moved to Lane 2, and placed SB as lift 3, Sections A and B. The mix changed to the PMB mix and Lane 2, Section D had lift 3 placed. The paving equipment then moved to Lane 1, and placed the PMB as lift 4 on Sections A and B. The equipment then moved to Lane 2 and placed the PMB as lift 4 on Sections A and B. The equipment then moved to Lane 1 and placed the PMB as lift 5, Sections A and B. The day's paving was then completed on Lane 2, placing the PMB mix as lift 5, Sections A and B.

### 5.3.3 June 2

The final paving operations were performed on June 2, 2003. Paving began with placement of the SMA on Lane 1, Section A, lift 6, which completed this section. Paving then moved to Lane 2, and the SMA was placed over Section A, lift 6, completing this section. Paving returned to Lane 1; the mixture changed to the DGS, and lift 6 was placed, completing Section B. The equipment moved to Lane 2 and continued placing the DGS to complete all sections here, lift 6 on Section B, lift 4 on Section D, and lift 2 on Section F.

Field notes kept during this construction by Tom Winkelman of IDOT are included in Appendix A. These notes detail the equipment used and any problems encountered during the construction, which were minimal. Due to the time schedule, the cooling of the individual lifts was limited but sufficient. The paver produced minimal ruts of one-eighth to one-quarter inch. In no instance was instability of the previously placed mix noted, and no hand work was ever required resulting from paving operations on a hot lift. Mix temperatures and appearance were satisfactory for all mixes with the exception of the SMA. It was noted that the SMA came with visible chunks of material that were suspected of being too cool to pave. These chunks were removed and hand patched during paving. The final surface was acceptable.

## 5.4 DENSITY MONITORING

Density was monitored with nuclear gauges from IDOT and Champaign Asphalt (CA) as the first section of a particular mixture was placed. Given the short nature of each section, it was impractical to generate rolling patterns separately from construction. The gauge was calibrated on a standard SB mix, and these settings were used for monitoring the test sections. When the gauge indicated a suitable level of density, that number of passes was utilized for the particular mixture being placed.

### 5.4.1 Nuclear Density Checks

All the density checks were made within 10-15 feet of the strain gauges in each of the test sections. A set of three density checks, equally spaced across the mat, were completed for each lift in each test section. At each of the three locations, two readings were taken and averaged to produce one nuclear density value; the three values across the mat were then averaged. While completing the checks for each lift, the rollers paused at the end of each test section and waited for the gauge operator to determine that the density of the lift was sufficient to proceed with the next lift. If the density was not sufficient, the rollers would make additional passes over the lift, and the density checks were repeated.

The results of the nuclear density monitoring program produced generally acceptable results, which are given in Appendix B. IDOT showed only 19 of 90 individual measurements producing an unacceptable density while CA showed 23 of 90 being unacceptable. When the values are averaged, IDOT shows only four of the 30 locations failing density, and CA shows six of the 30 locations failing density. There were three cases where both agencies reported failing nuclear densities: Lane 1, Section A, lift 6; Lane 2, Section D, lift 4; and Lane 2, Section F, lift 1.

### 5.4.1 Core Density Checks

Once construction of each individual mixture was completed, core samples were taken from the test sections at the same locations as the nuclear density checks. At each location, three cores were taken for quality control (QC) testing and three cores were taken for quality assurance (QA) testing. One additional core was taken near the gauge installation, primarily for thickness determination, but density was determined also. The core density values were to adhere to the specifications in Table 9.

Table 9. Core Density Requirements

| Bituminous Layer | N Design | Control Limits |
|---|---|---|
| Rich bottom base | Any value used | 94.0-97.0% Gmm |
| Polymerized binder and standard binder | ≥ 90 | 92.0-96.0% Gmm |
| Dense graded surface | ≥ 90 | 92.0-96.0% Gmm |
| SMA surface | Any value used | 93.5-97.4% Gmm |

Schematics of the density recording and coring locations are shown in Figures 31 and 32. In all cases, the cores and density readings were offset by three feet for each different mixture to avoid coring over previously cored areas. A photo of the final surface with gauge locations and core locations of the surface mixture is presented in Figure 33?.

The core density values are given in Appendix B. The core densities generally followed the trend seen in the nuclear tests. The average density (percent of $G_{mm}$) for each mixture are as follows, for IDOT and CA testing respectively, RBB (96.6, 96.8, or an average 96.7 percent density), Std Binder (94.7, 94.8, or an average 94.7 percent density), PMB (93.6, 93.3, or an average 93.5 percent density), DGS (93.7, 93.5, or an average 93.6 percent density) and the SMA (94.1, 92.9, or an average 93.5 percent density). The RBB mix was lowest in voids, which was desirable given the high asphalt content nature of this mix. The SMA showed the only failing density value for the CA testing, and it is on the low side.

The individual IDOT tests showed 22 of the 90 individual tests failing. The CA tests indicated 28 of the 90 individual tests failing. For the IDOT tests, 16 of the 22 tests failed with high density (low air voids). For the CA tests, 14 of the 28 tests failed for high density (low air voids). Slightly more (60 percent to 40 percent) of the individual tests failed due to over-compaction. This could relate to the short length of the sections, and the lack of a traditional rolling pattern which required continual adjustments to the number of passes. In general, the average densities or air voids for each mixture indicate reasonable results. These density or air void levels show good correlation with the compaction results on the field sampled mix, to be discussed in the composition section.

Averaging the individual values for each lift placed, IDOT data indicates that 1A3 (Lane 1, Section A, lift 3), 1A6, 2A3, 1B1, 1B3, and 2B3 would be the only lifts failing core density checks. The CA data would indicate that 1A3, 1A6, 2A3, 2A5, 1B1, 1B3, 1B5, 2B3, and 2B5 would fail the core density checks. If the values are rounded to only two significant figures, most of these would meet the specification limit. For the cores, there were six locations where both agencies showed failing density, 1A3, 1A6, 2A3, 1B1, 1B3, and 2B3 the first paving of day two, using the standard binder.

HMA Extended Life Pavement Density Testing and Coring Layout
Lane 1

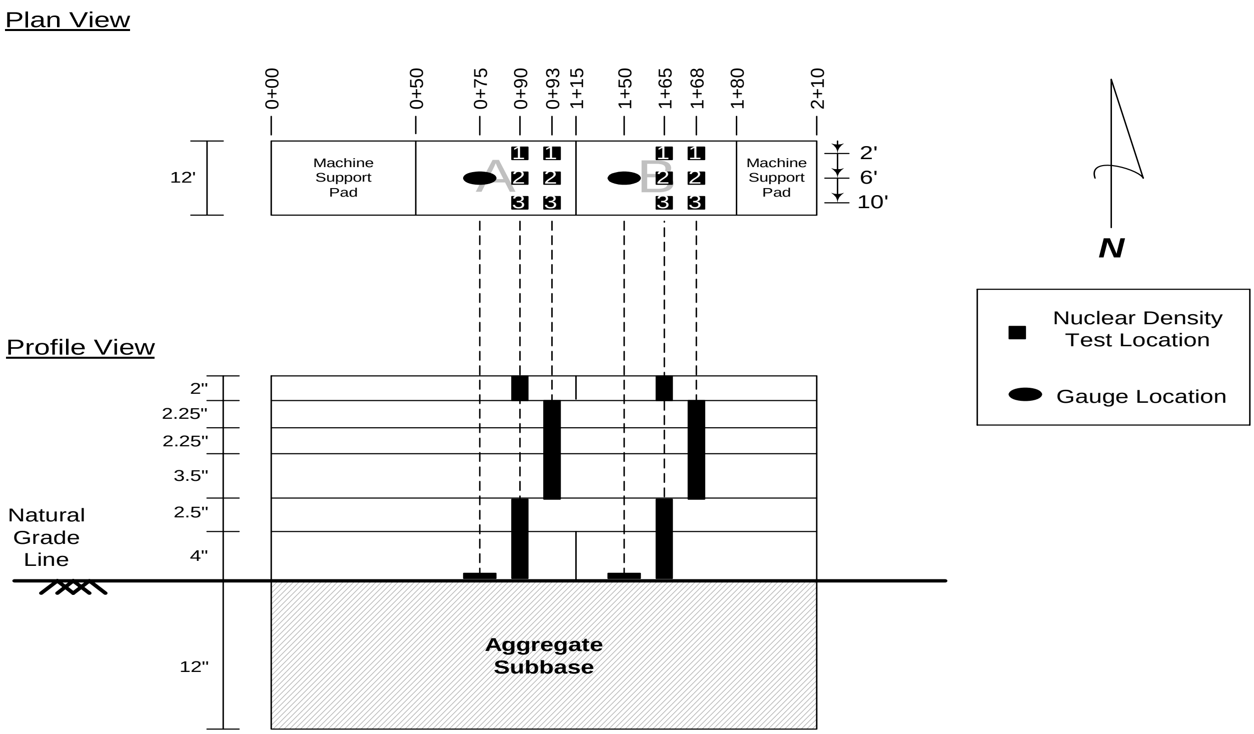



Figure 31. Coring and density locations for Lane 1.

HMA Extended Life Pavement Density Testing and Coring Layout
Lane 2

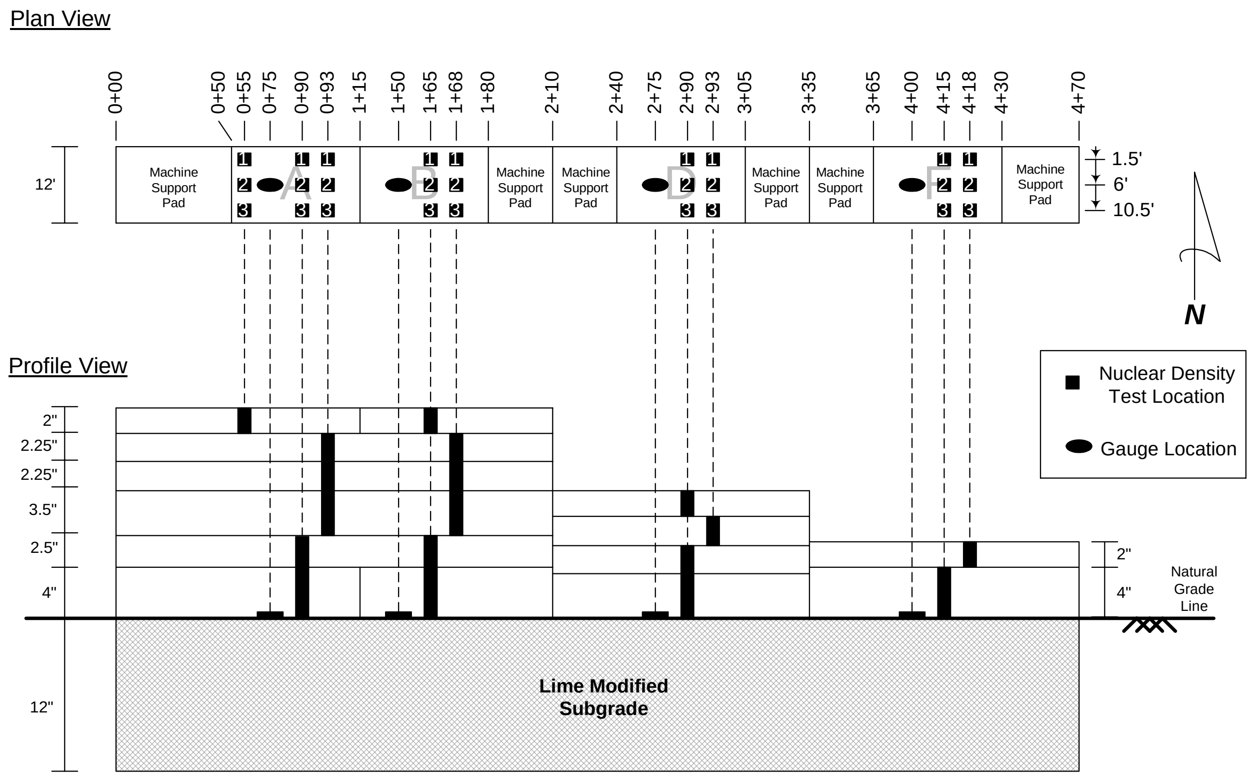



Figure 32. Coring and density locations for Lane 2.

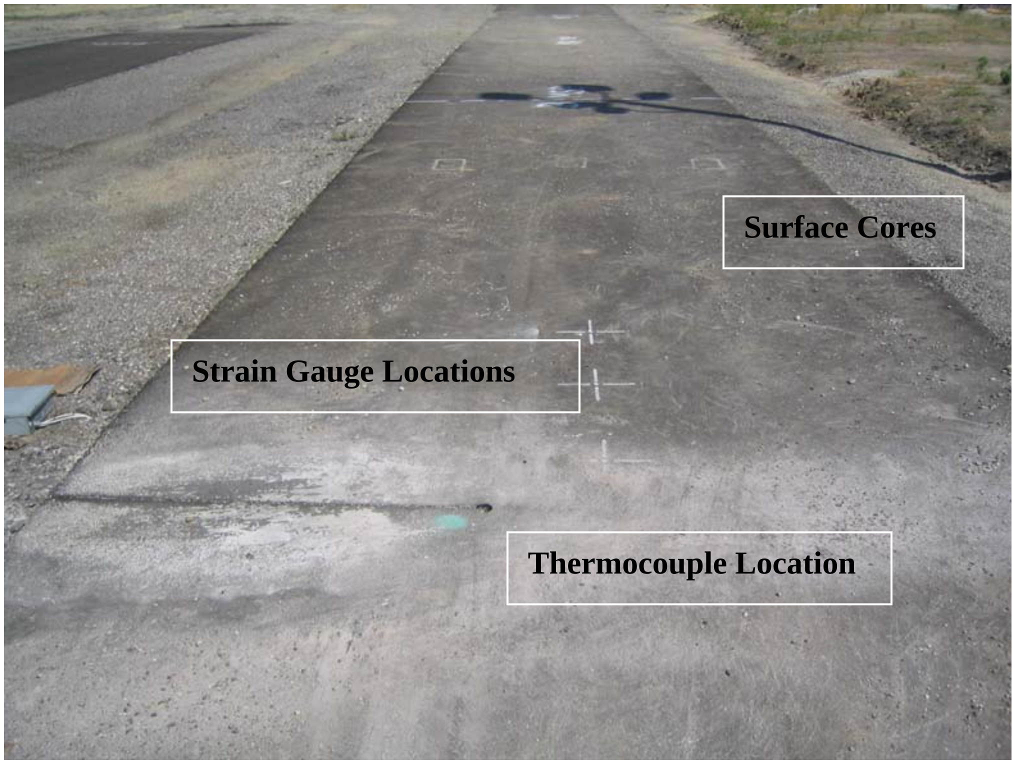



Figure 33. Completed surface showing strain gauge locations, thermocouple location, and core locations relative to strain gauge locations.

**5.5 THICKNESS MEASUREMENTS**

The cores taken for density corrections were also measured for thickness compliance to ensure that the final thickness was as called for in the plans. This was necessary for accurate computer simulations of pavement responses under the moving ATLAS wheel load, and for the FWD analyses to be conducted.

The thickness measurements for each lift for IDOT and CA cores are given in Appendix B. The average total thicknesses for the sections are as follows:

- Lane 1
  - Section A
    - CA – 18.0 inches
    - IDOT – 18.6 inches
  - Section B
    - CA – 15.5 inches
    - IDOT – 16.7 inches
  - Section D
    - CA – 9.8 inches
    - IDOT – 10 inches
  - Section F
    - CA – 5.1 inches
    - IDOT – 5.2 inches

- Lane 2

- Section A
  - CA - 15.9 inches
  - IDOT – 16.4 inches
- Section B
  - CA – 15.8 inches
  - IDOT – 16.3 inches

Following final construction, 2-inch diameter cores were taken for thermocouple placement. These cores were taken close to the strain gauge locations as shown in Figure 33?. This coring provided independent thickness measurements close to the strain gauges for use in structural analysis and for comparison to the results from individual mixture layer cores. Lane 1, Sections A and B measured 16.5 inches thick. In Lane 2, Sections A and B measured 16.5 and 15.5 inches respectively. Section D did not recover a complete core, and Section F measured 6 inches (3 inches surface, 3 inches binder). These thicknesses were used for computer modeling purposes because the strain gauge readings under load are representative of the thicknesses at the gauge locations.

## 5.6 CONSTRUCTION AND COMPOSITION RESULTS

Testing was conducted on the cores and on mix samples taken at the time of mixture production at the plant. The tests include indirect tensile strength, stripping evaluation, asphalt content determination, and gradation determination. The tensile strength and stripping evaluation results are given in Appendix B.

### 5.6.1 Indirect Tensile Strength

Indirect tensile strength tests and a strip rating test were performed on the core samples. The indirect tensile strength is an indicator of mix quality. The average and range of indirect tensile strengths (run on unconditioned cores) for the mixture types used in the ELHMAP sections are as follows:

- Dense-graded surface (DGS) – 118 psi (89 – 136 psi for 12 samples)
- SMA surface (SMA) – 133 psi (116 – 150 psi for 6 samples)
- Standard Binder (SB) – 111 psi (78 – 140 psi for 36 samples)
- Polymer-modified binder (PMB) – 124 psi (93 – 164 psi for 30 samples)
- Rich bottom binder (RBB) – 84 psi (78 – 92 psi for 6 samples)

These values are typical of expected values for HMA. The RBB mixture is lower, but this is to be expected with the extra 0.5 percent asphalt added.

### 5.6.2 Strip Rating

Following the splitting of the samples in the indirect tensile strength test, the broken surfaces were visually examined and assigned a strip rating. The coarse and fine aggregate fractions were examined and rated. The examination involved estimating the relative percent of the aggregate surface that had lost the coating of asphalt due to moisture activity. The rating was as follows:

- 1 – There was less than 10 percent exposed aggregate
- 2 – There was between 10 and 40 percent exposed aggregate
- 3 – There was greater than 40 percent exposed aggregate

These individual ratings for cores taken from construction of a specific mixture can be combined into a composite rating by summing 0.4 times the coarse aggregate rating and 0.6 times the fine aggregate rating. However, no composite rating was needed for the ATREL mixtures as no stripping potential was noted - all mixtures and all aggregate sizes received a rating of 1. For these mixtures, with the exception of the SMA, the excellent resistance to moisture damage could be attributed to the lime slurry treatment of the aggregate, which has shown benefit. The SMA, which had hydrated lime added dry as a filler, is by nature strip resistant due to the fiber and extra asphalt content, so its performance may not be directly attributed to the hydrated lime addition. No differences in the mixtures during placement were noted.

**5.6.3 Permeability**

A field permeability test was conducted on the surface lift of each test section and on a few binder lifts in various test sections. This test is a falling head permeability test that records the time it takes for water in a vertical tube to fall a specified distance. The longer it takes for the water level to fall, the lower the permeability of the mixture. This field test allows the water to flow into the surface of the mix, through the interconnected voids, and then it is allowed to flow outward from the permeameter. Thus the water does not flow completely through the mixture and the permeability value that is determined is not representative of the entire mix, but only the near surface void structure. Therefore this test is considered informational, and representative of only the near surface characteristics.

The criteria for this test is that for surface courses, permeability $\leq 100 \times 10^{-5}$ cm/sec correlates to densities of 92% or better, and for binder courses, permeability $\leq 120 \times 10^{-5}$ cm/sec correlates to densities of 94.5% or better. The following permeabilities (cm/sec x $10^{-5}$) were obtained at the indicated lane/location/lifts for the mixes indicated. (NOTE – Permeability locations do not necessarily correspond to nuclear or core density locations listed in Appendix B. Nuclear density readings, along with the offset at the permeability location, where known, are noted below.):

- 05/29/2003
    - 2F1 – SB – 501 (density unknown; 2 ft. from edge)
    - 2A2 – SB – 7122 (92.8%; center of lane)
    - 2A2 – SB – 1463 (93.9%; 4 ft. from edge)
    - 2A2 – SB – 13589 (89.3%; 6 inches from edge)
- 05/30/2003
    - 1A3 – SB – 18218 (92.6%; offset unknown)
    - 1A3 – SB – 1457 (92.6%; offset unknown)
    - 1A3 – SB – 524 (95.1%; offset unknown)
- 06/02/2003
    - 1A6 – SMA – 5793 (90.3%; sensor location, center line)
    - 1B6 – DGS – 79 (94.2%; sensor location, center line)
    - 2A6 – SMA – 11624 (89.7%; sensor location, center line)
    - 2B6 – DGS – 480 (95.5%; sensor location, center line)
    - 2D4 – DGS – 44 (96.4%; sensor location, center line)
    - 2F2 – DGS – 151 (94.5%; sensor location, center line)

The permeability readings followed the generally accepted density-permeability relationships.

### 5.6.4 Composition

Composition tests were conducted on split samples taken at the time of mixture production at the plant. Samples went to CA and IDOT. Appendix C contains the split sample results for gradation and asphalt content for CA and IDOT. The gradation control between job mix formula and field samples was acceptable. The comparison of in-place air voids and the air voids obtained in the lab compaction of field samples, is given in Table 10. As expected, laboratory voids are closer to the mix design than the field levels, given that mix design and laboratory compaction are designed to relate to long term densification under traffic.

Table 10. Void Levels for Mix Design and Field Production

| **Dense Graded Surface (DGS) (6/2)** | | | |
|---|---|---|---|
| | Mix Design | CA - Production | IDOT - Production |
| Asphalt Content | 5.4 | 5.6 | 5.5 |
| Lab Air Voids | 4.0 | 5.1 | 5.1 |
| In-Place Air Voids | - | 6.3 | 6.3 |
| **SMA Surface (SMA) (6/2)** | | | |
| | Mix Design | CA - Production | IDOT – Production |
| Asphalt Content | 5.4 | 5.5 | 5.1 |
| Lab Air Voids | 4.0 | 2.9 | 2.9 |
| In-Place Air Voids | - | 6.9 | 6.9 |
| **Standard Binder (SB) (5/29, 5/30)** | | | |
| | Mix Design | CA - Production | IDOT – Production |
| Asphalt Content | 4.5 | 4.8, 5.4 | .0, 5.7 |
| Lab Air Voids | 4.0 | 3.3, 1.9 | 3.5, 1.6 |
| In-Place Air Voids | - | 6.1, 4.5 | 6.4, 3.0 |
| **Polymer Modified Binder (PMB) (5/29, 5/30)** | | | |
| | Mix Design | CA - Production | IDOT - Production |
| Asphalt Content | 4.5 | 4.2, 4.4 | 4.4, 4.6 |
| Lab Air Voids | 4.0 | 3.7, 2.9 | 3.8, 2.9 |
| In-Place Air Voids | - | 8.2,6.1 | 8.2, 6.1 |
| **Rich Bottom Binder (RBB) (5/29)** | | | |
| | Mix Design | CA - Production | IDOT - Production |
| Ashalt Content | 5.1 | 4.4 | 4.7 |
| Lab Air Voids | 2.5 | 1.9, 1.0 | 1.6, 0.7 |
| In-Place Air Voids | - | 3 | |

# CHAPTER 6 CLOSURE

The testing done during grade preparation and construction shows that an acceptable pavement was constructed with quantified material properties that will allow response testing to be conducted to provide comparison data for the ILLI-PAVE computer analysis.

Grade preparation indicates that lime-modification was successful in providing a good working platform. The aggregate subbase achieved good density and provided a good working platform. Both prepared grades indicated good resistance to moisture during the rainstorm. The uniformity of the construction was acceptable with the aggregate subbase providing very good uniformity. The soft spot that required undercutting and backfilling was under a machine support pad and not in a test section.

Construction of the HMA proceeded as planned with no major problems during the three days of paving. Even with the constant changing of mixtures during paving, the mixture composition was good. Some thickness variability was observed during construction of the individual lifts, but the final thicknesses of each mixture and the overall section thicknesses were sufficient. The thicknesses over the strain gauges were as per specification although variation along the length of the project produced some thick and thin sections.

The construction clearly produced sections containing the ELHMAP characteristics set forth by IDOT. No major deficiencies were present that would produce anomalies in a structural analysis of the ELHMAP sections. The response and test parameters generated from these sections should provide data that can be considered representative of pavements being constructed from current materials and will be used to accomplish the remaining work tasks of the IHR-R39 project.

# REFERENCES

Illinois Department of Transportation Geotechnical Manual, Attachment II-A

# APPENDIX A

# IDOT CONSTRUCTION NOTES FOR HMA PAVING

HMA Extended Life Pavement at ATREL
Construction Notes (Tom Winkelman)

**Construction Equipment**

| | | | |
|---|---|---|---|
| Material Transfer Device | RoadTec Shuttle Buggy SB2500B | | |
| Paving Machine | Blaw-Knox (Ingersoll-Rand) PF-5510 (Tracked) | | |
| Breakdown Roller | Ingersoll-Rand DD-90HF (Vibratory) | | |
| | | Operating Weight (tons) | 10.9 |
| | | Drum Width (in) | 66 |
| | | Vibration Frequency (/min) | 3,800 |
| Breakdown Roller (SMA only) | Ingersoll-Rand DD-110HF (Static) | | |
| | | Operating Weight (tons) | 12.7 |
| | | Drum Width (in) | 78 |
| Finish Roller | HyPac C350D (Static) | | |
| | | Operating Weight (tons) | 8.2 |
| | | Drum Width (in) | 54 |
| | | Maximum Speed (mph) | 10.2 |

| | |
|---|---|
| Tandem Truck # 1 | David Ault Trucking, Rossville, IL., License 7431, Black and Silver |
| Tandem Truck # 2 | Reitz Trucking, Gifford, IL., License 12196, Purple and Silver |
| Tandem Truck # 3 | L. Smith Trucking, Hume, IL., License 14334, Red and Black |
| Tandem Truck # 4 | Lewis Farms, Paxton, IL., License 7820, Tan and Black |
| Tandem Truck # 5 | Smith & Bell Trucking, Hume, IL., License 17833, White |
| Tandem Truck # 6 | Champaign Trucks, Champaign, IL., License 13481, Blue |
| Tandem Truck # 7 | Tim’s Trucking, Urbana, IL., License P130669, Red |
| Tandem Truck # 8 | Champaign Trucks, Champaign, IL., License 10116, Black |
| Tandem Truck # 9 | Les Hahn Trucking, License 21041, White |

1 Prime Coat Application Truck
1 Water Truck
1 John Deere Backhoe
1 Motor Grader

HMA Extended Life Pavement at ATREL
Construction Notes (Tom Winkelman)

**May 29, 2003**

**Lane 2, Lift 1 Paving Sections A – Rich Bottom Binder**
**Sections B, D, F – Standard Binder**

1st truck arrives at 7:35 and unloads at 7:47.
2nd truck arrives at 7:40 and unloads at 7:52.
3rd truck arrives at 7:54 and unloads at 7:56.
4th truck arrives at 8:03 and unloads at 8:07.
5th truck arrives at 8:05 and unloads at 8:21.
6th truck arrives at 8:15 and unloads at 8:25.
7th truck arrives at 9:05 and unloads at 9:05.
8th truck arrives at 9:05 and unloads at 9:08.
9th truck arrives at 9:15 and unloads at 9:19.
10th truck arrives at 9:26 and unloads at 9:27.
11th truck arrives at 9:26 and unloads at 9:32.

Paving begins at 7:50 and ends at 9:40.
Breakdown rolling begins at 7:56.
Finish rolling begins at 8:45.

- Tandem truck numbers 1 through 6 were used to haul mix.
- Paving operations proceeded from west to east.
- Paving stopped at 7:58 and started again at 8:21. Paving stopped a second time at 8:30 and started again at 9:05. These delays were a result of waiting on trucks to deliver mix.
- Three truck loads were used to pave the Rich Bottom Binder area.
- Paving proceeded strait through the machine support pad area and Section A with no stop for the growth curve.
- The transition from Rich Bottom Binder to Standard Binder at the A-B transition point was made right on the correct station. The transition was made on the fly, no butt joint was made.
- The first pass of the breakdown roller was down the middle of the lane, and it was in vibratory mode.
- Adjustments to paving thickness (4” to 3.5”) were made during the B-D transition area, however no adjustment (3.5” to 4”) was apparent during the D-F transition.

**May 29, 2003**

**Lane 1, Lift 1 Paving Section A – Rich Bottom Binder**
**Section B – Standard Binder**

1st truck arrives at 9:35 and unloads at 10:28.
2nd truck arrives at 10:07 and unloads at 10:11.
3rd truck arrives at 10:16 and unloads at 10:19.
4th truck arrives at 10:19 and unloads at 10:22.
5th truck arrives at 10:28 and unloads at 10:34.
6th truck arrives at 10:45 and unloads at 10:48.
7th truck arrives at 10:47 and unloads at 10:51.

Paving begins at 10:19 and ends at 10:55.
Breakdown rolling begins at 10:25.
Finish rolling begins at 11:45.

- Tandem truck numbers 1 through 6 were used to haul mix.
- Paving operations proceeded from west to east.
- The 2nd, 3rd, and 4th trucks contained the Rich Bottom Binder mix. The 1st truck hauled Standard Binder left over from lane 2, and therefore unloaded at the A-B transition point.
- The transition from Rich Bottom Binder to Standard Binder at the A-B transition point was made about 5-feet prior to the correct station. The transition was made on the fly, no butt joint was made.
- The first pass of the breakdown roller was down the middle of the lane, and it was in vibratory mode.

**May 29, 2003**

**Lane 2, Lift 2 Paving Sections A, B – Standard Binder**

1st truck arrives at 11:10 and unloads at 11:16.
2nd truck arrives at 11:24 and unloads at 11:25.
3rd truck arrives at 11:38 and unloads at 11:40.
4th truck arrives at 11:40 and unloads at 11:44.

Paving begins at 11:17 and ends at 11:46.
Breakdown rolling begins at 11:20.
Finish rolling begins at 12:45.

**Lane 2, Lift 2 Paving Section D – Polymerized Binder**

1st truck arrives at 1:40 and unloads at 1:42.
2nd truck arrives at 1:47 and unloads at 1:55.
3rd truck arrives at 1:55 and unloads at 2:05.

Paving begins at 1:44 and ends at 2:10.
Breakdown rolling begins at 1:47.
Finish rolling begins at 2:45.

- Tandem truck numbers 1 through 6 were used to haul mix.
- Paving operations proceeded from west to east.
- The polymer tack coat was not allowed to cure/break before placement of lift 2. Paving started within 10 minutes after placement of the polymer tack coat. Bill Pine from Heritage Research Group claimed that the polymer tack coat will break under the heat of the paving machine and screed just before the mix is placed on it.
- Sections D & F of lane 2 received a second application of tack coat on top of the first lift.
- A butt joint was made at the end of Section B in lane 2 at the transition from Standard Binder to Polymerized Binder.
- The paving machine rutted the first lift of binder as it backed down the lane to prepare for paving of the second lift. The depth of rut was approximately 1/8-inch to 1/4-inch.
- At the conclusion of paving for the Polymerized binder in Section D, the material was ramped down to nothing in the machine support pad area between Sections D and F. No butt joint was made.

**May 29, 2003**

**Lane 1, Lift 2 Paving Sections A, B – Standard Binder**

1st truck arrives at 11:58 and unloads at 12:00.
2nd truck arrives at 12:27 and unloads at 12:29.
3rd truck arrives at 12:32 and unloads at 12:34.

Paving begins at 12:07 and ends at 12:37.
Breakdown rolling begins at 12:10.
Finish rolling begins at 1:30.

- Tandem truck numbers 1 through 6 were used to haul mix.
- Paving operations proceeded from west to east.
- The polymer tack coat was not allowed to cure/break before placement of lift 2. Paving started within 10 minutes after placement of the polymer tack coat. Bill Pine from Heritage Research Group claimed that the polymer tack coat will break under the heat of the paving machine and screed just before the mix is placed on it.
- The paving machine rutted the first lift of binder as it backed down the lane to prepare for paving of the second lift. The depth of rut was approximately 1/8-inch to 1/4-inch.

**May 30, 2003**

**Lane 1, Lift 3 Paving        Sections A, B – Standard Binder**

1st truck arrives at 7:35 and unloads at 7:36.
2nd truck arrives at 7:35 and unloads at 7:39.
3rd truck arrives at 7:35 and unloads at 7:42.
4th truck arrives at 7:52 and unloads at 7:55.
5th truck arrives at 7:55 and unloads at 7:58.

Paving begins at 7:38 and ends at 8:05.
Breakdown rolling begins at 7:45.
Finish rolling was not done.  The mat temperature was to hot.

- Tandem truck numbers 2 through 7 were used to haul mix.
- Paving operations proceeded from west to east.
- Core holes were filled with material from the paving machine and compacted with a Marshall hammer.

**May 30, 2003**

**Lane 2, Lift 3 Paving        Sections A, B – Standard Binder**

1st truck arrives at 8:07 and unloads at 8:10.
2nd truck arrives at 8:35 and unloads at 8:37.
3rd truck arrives at 8:35 and unloads at 8:43.
4th truck arrives at 8:37 and unloads at 8:48.

Paving begins at 8:39 and ends at 8:50.
Breakdown rolling begins at 8:50.
Finish rolling was not done.  The mat temperature was to hot.

**Lane 2, Lift 3 Paving        Section D – Polymerized Binder**

1st truck arrives at 9:01 and unloads at 9:14.
2nd truck arrives at 9:20 and unloads at 9:23.

Paving begins at 9:16 and ends at 9:29.
Breakdown rolling begins at 9:20.
Finish rolling was not done.  The mat temperature was to hot.

- Tandem truck numbers 2 through 7 were used to haul mix.
- Paving operations proceeded from west to east.
- Core holes were filled with material from the paving machine and compacted with a Marshall hammer.
- Paving of the Standard Binder was stopped in the B-D transition zone.  The MTD and paving machine were cleaned out, and paving of the Polymerized Binder resumed at the same location.  There was no butt joint created here.
- Paving of the Polymerized Binder in Section D was ramped down to nothing in the transition zone between Sections D and F.  There was no butt joint created here.

**May 30, 2003**

**Lane 1, Lift 4 Paving Sections A, B – Polymerized Binder**

1st truck arrives at 9:45 and unloads at 9:54.
2nd truck arrives at 9:47 and unloads at 9:59.
3rd truck arrives at 9:50 and unloads at 9:56.

Paving begins at 9:56 and ends at 10:07.
Breakdown rolling begins at 10:15.
Finish rolling was not done. The mat temperature was to hot.

- Tandem truck numbers 2 through 7 were used to haul mix.
- Paving operations proceeded from west to east.
- The paving machine rutted the previous lift of binder as it backed down the lane to prepare for paving of this lift. The depth of rut was approximately 1/8-inch to 1/4-inch.
- The polymer tack coat was not allowed to cure/break before placement of this lift. Paving started within 10 minutes after placement of the polymer tack coat.

**May 30, 2003**

**Lane 2, Lift 4 Paving        Sections A, B – Polymerized Binder**

1st truck arrives at 10:05 and unloads at 10:14.
2nd truck arrives at 10:14 and unloads at 10:42.
3rd truck arrives at 10:36 and unloads at 10:51.

Paving begins at 10:49 and ends at 10:56.
Breakdown rolling begins at 10:56.
Finish rolling was not done. The mat temperature was to hot.

- Tandem truck numbers 2 through 7 were used to haul mix.
- Paving operations proceeded from west to east.
- The paving machine rutted the previous lift of binder as it backed down the lane to prepare for paving of this lift. The depth of rut was approximately 1/8-inch to 1/4-inch.
- The polymer tack coat was not allowed to cure/break before placement of this lift. Paving started within 10 minutes after placement of the polymer tack coat.
- Paving of the Polymerized Binder in Section B was ramped down to nothing in the transition zone between Sections B and D. There was no butt joint created here.

**May 30, 2003**

**Lane 1, Lift 5 Paving        Sections A, B – Polymerized Binder**

1st truck arrives at 11:24 and unloads at 11:25.
2nd truck arrives at 11:28 and unloads at 11:28.
3rd truck arrives at 11:28 and unloads at 11:32.

Paving begins at 11:26 and ends at 11:38.
Breakdown rolling begins at 11:38.
Finish rolling was not done. The mat temperature was too hot.

- Tandem truck numbers 2 through 7 were used to haul mix.
- Paving operations proceeded from west to east.
- The paving machine rutted the previous lift of binder as it backed down the lane to prepare for paving of this lift. The depth of rut was approximately 1/8-inch to 1/4-inch.
- The polymer tack coat was not allowed to cure/break before placement of this lift. Paving started within 10 minutes after placement of the polymer tack coat.

**May 30, 2003**

**Lane 2, Lift 5 Paving Sections A, B – Polymerized Binder**

1st truck arrives at 11:35 and unloads at 11:42.
2nd truck arrives at 11:44 and unloads at 11:51.

Paving begins at 11:49 and ends at 11:59.
Breakdown rolling begins at 12:00.
Finish rolling was not done. The mat temperature was to hot.

- Tandem truck numbers 2 through 7 were used to haul mix.
- Paving operations proceeded from west to east.
- The paving machine rutted the previous lift of binder as it backed down the lane to prepare for paving of this lift. The depth of rut was approximately 1/8-inch to 1/4-inch.
- The polymer tack coat was not allowed to cure/break before placement of this lift. Paving started within 10 minutes after placement of the polymer tack coat.
- Paving of the Polymerized Binder in Section B was ramped down to nothing in the transition zone between Sections B and D. There was no butt joint created here.

**June 2, 2003**

**Lane 1, Lift 6 Paving        Section A – SMA Surface**

1st truck arrives at 8:47 and unloads at 8:54.
2nd truck arrives at 8:47 and unloads at 8:58.

Paving begins at 8:58 and ends at 9:05.
Breakdown rolling begins at 9:02.
Finish rolling begins at 9:30.

**Lane 1, Lift 6 Paving        Section B – Dense Graded Surface**

1st truck arrives at 10:30 and unloads at 10:42.
2nd truck arrives at 10:30 and unloads at 10:45.

Paving begins at 10:44 and ends at 10:51.
Breakdown rolling begins at 10:45.
Finish rolling begins at 11:45.

- Tandem truck numbers 6 through 9 were used to haul mix.
- Paving operations proceeded from west to east.
- The SMA Surface mix was loaded out of the Marshall plant at 6:45 to 7:00.
- The SMA Surface looks and acts clumpy.
- The SMA Surface had some cold chunks in it that stuck under the screed and ripped the mat in 2-3 places.  The tears were filled and struck off by hand.
- The SMA Surface paving stopped a few feet beyond the station for transition between Sections A and B.  A butt joint was made at the correct station.  The backhoe back end bucket was used to scrape the excess material off of the pavement.
- The Dense Graded Surface looked and compacted very good.

**June 2, 2003**

**Lane 2, Lift 6 Paving Section A – SMA Surface**

1st truck arrives at 8:51 and unloads at 9:30.
2nd truck arrives at 8:51 and unloads at 9:39.

Paving begins at 9:40 and ends at 10:03.
Breakdown rolling begins at 9:42.
Finish rolling begins at 10:40.

**Lane 2, Lift 6 Paving Section B – Dense Graded Surface**
**Lift 4 Paving Section D – Dense Graded Surface**
**Lift 2 Paving Section F – Dense Graded Surface**

1st truck arrives at 10:54 and unloads at 10:56.
2nd truck arrives at 10:55 and unloads at 11:02.
3rd truck arrives at 11:52 and unloads at 11:54.
4th truck arrives at 11:52 and unloads at 11:56.

Paving begins at 11:00 and ends at 12:03.
Breakdown rolling begins at 11:05.
Finish rolling begins at 12:45.

- Tandem truck numbers 6 through 9 were used to haul mix.
- Paving operations proceeded from west to east.
- The SMA Surface mix was loaded out of the Marshall plant at 6:45 to 7:00.
- The SMA Surface looks and acts clumpy.
- The SMA Surface had some cold chunks in it that stuck under the screed and ripped the mat in 2-3 places. The tears were filled and struck off by hand.
- The SMA Surface paving stopped 25 feet prior to the station for transition between Sections A and B. A butt joint was made at this location. The backhoe back end bucket was used to scrape the excess material off of the pavement. This butt joint is directly over the location where densities were taken on the first two lifts. The butt joint is roughly 15 feet from the sensor location for Section A.
- Dirt and rocks were tracked up onto the pavement surface in the B-D transition zone as the paving machine took a short cut from lane 1 to lane 2. The back hoe operator attempted to clean it off with the front bucket.
- The Dense Graded Surface looked and compacted very good.

# APPENDIX B

# NUCLEAR DENSITY, CORE DENSITY, THICKNESS RESULTS

## ATREL CORE DENSITY SUMMARY

| ID | BMPR RESULTS | | | | | | | | CHAMPAIGN ASPHALT RESULTS | | | | | | I. PRODUCTION | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LOCATION | | | | | | | | LOCATION | | | | | | II. | | |
| | 1 % den. | P/F | 2 % den. | P/F | 3 % den. | P/F | SENSOR % den. | P/F | 1 % den. | P/F | 2 % den. | P/F | 3 % den. | P/F | MIX | DATE LAID | TARGET DENSITY |
| 1A1 | 96.4 | P | 96.5 | P | 97.2 | F | 95.7 | P | 96.4 * | P | 96.8 * | P | 97.6 * | F | RB Bind. | 5/29/03 | 94.0 – 97.0 |
| 1A2 | 93.3 | P | 92.8 | P | 93.5 | P | 92.0 | P | 93.6 * | P | 93.6 * | P | 93.7 * | P | Std. Bind. | 5/29/03 | 92.0 – 96.0 |
| 1A3 | 97.3 | F | 96.8 | F | 95.7 | P | 97.2 | F | 97.3 | F | 96.4 | F | 95.4 | P | Std. Bind. | 5/30/03 | 92.0 – 96.0 |
| 1A4 | 96.5 | F | 94.8 | P | 95.6 | P | 95.0 | P | 96.1 | F | 94.8 | P | 95.4 | P | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 1A5 | 93.3 | P | 93.7 | P | 93.2 | P | 93.1 | P | N/A | | 93.6 | P | 92.4 | P | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 1A6 | 93.7 | P | 92.9 | F | 93.7 | P | 93.9 | P | 92.4 | F | 91.7 | F | 92.3 | F | SMA Surf. | 6/02/03 | 93.5 – 97.4 |
| 2A1 | 96.3 | P | 97.2 | F | 96.2 | P | 97.2 | F | 96.3 * | P | 97.2 * | F | 96.0 * | P | RB Bind. | 5/29/03 | 94.0 – 97.0 |
| 2A2 | 92.3 | P | 93.9 | P | 93.0 | P | 92.9 | P | 92.8 * | P | 94.3 * | P | 92.8 * | P | Std. Bind. | 5/29/03 | 92.0 – 96.0 |
| 2A3 | 96.5 | F | 96.1 | F | 96.3 | F | 97.9 | F | 96.3 | F | 95.5 | P | 96.4 | F | Std. Bind. | 5/30/03 | 92.0 – 96.0 |
| 2A4 | 95.5 | P | 95.3 | P | 95.5 | P | 94.1 | P | 95.4 | P | 95.6 | P | 95.4 | P | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 2A5 | 92.2 | P | 92.4 | P | 92.2 | P | 92.2 | P | 91.6 | F | 91.8 | F | 91.3 | F | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 2A6 | 94.9 | P | 92.6 | F | 94.9 | P | 88.4 | F | 94.5 | P | 91.8 | F | 94.5 | P | SMA Surf. | 6/02/03 | 93.5 – 97.4 |
| 1B1 | 95.9 | P | 96.5 | F | 96.6 | F | 96.9 | F | 96.0 * | P | 97.2 * | F | 96.8 * | F | Std. Bind. | 5/29/03 | 92.0 – 96.0 |
| 1B2 | 91.4 | F | 93.5 | P | 92.9 | P | 90.9 | F | 92.8 * | P | 95.0 * | P | 93.8 * | P | Std. Bind. | 5/29/03 | 92.0 – 96.0 |
| 1B3 | 96.9 | F | 97.5 | F | 97.0 | F | 98.5 | F | 95.3 | P | 97.3 | F | 96.2 | F | Std. Bind. | 5/30/03 | 92.0 – 96.0 |
| 1B4 | 95.3 | P | 95.5 | P | 95.7 | P | 94.7 | P | 95.6 | P | 95.8 | P | 95.4 | P | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 1B5 | 91.3 | F | 92.9 | P | 92.5 | P | 92.3 | P | 90.9 | F | 92.9 | P | 91.7 | F | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 1B6 | 94.3 | P | 94.0 | P | 91.5 | F | 92.4 | P | 94.0 | P | 94.3 | P | 90.4 | F | DG Surf. | 6/02/03 | 92.0 – 96.0 |
| 2B1 | 95.3 | P | 95.3 | P | 93.9 | P | 92.9 | P | 95.2 * | P | 95.0 * | P | 93.9 * | P | Std. Bind. | 5/29/03 | 92.0 – 96.0 |
| 2B2 | 93.1 | P | 92.8 | P | 92.3 | P | 94.0 | P | 92.9 * | P | 92.8 * | P | 92.4 * | P | Std. Bind. | 5/29/03 | 92.0 – 96.0 |
| 2B3 | 97.2 | F | 97.3 | F | 96.0 | P | 97.2 | F | 97.1 | F | 97.5 | F | 96.3 | F | Std. Bind. | 5/30/03 | 92.0 – 96.0 |
| 2B4 | 95.7 | P | 95.1 | P | 94.7 | P | 93.9 | P | 95.8 | P | 95.1 | P | 94.7 | P | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 2B5 | 92.5 | P | 92.4 | P | 91.1 | F | 91.6 | F | 92.0 | P | 92.1 | P | 90.7 | F | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 2B6 | 95.2 | P | 93.0 | P | 94.5 | P | 93.8 | P | 95.2 | P | 93.0 | P | 94.1 | P | DG Surf. | 6/02/03 | 92.0 – 96.0 |
| 2D1 | 93.8 | P | 94.2 | P | 93.1 | P | 91.1 | F | 93.2 * | P | 93.8 * | P | 92.6 * | P | Std. Bind. | 5/29/03 | 92.0 – 96.0 |
| 2D2 | 92.3 | P | 91.8 | F | 92.5 | P | 90.6 | F | 92.3 * | P | 91.4 * | F | 92.3 * | P | Poly Bind. | 5/29/03 | 92.0 – 96.0 |
| 2D3 | 93.7 | P | 93.5 | P | 93.3 | P | 92.0 | P | 93.7 | P | 91.8 | F | 93.2 | P | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 2D4 | 94.9 | P | 95.7 | P | 94.5 | P | 94.2 | P | 95.5 | P | 95.1 | P | 94.7 | P | DG Surf. | 6/02/03 | 92.0 – 96.0 |
| 2F1 | 93.5 | P | 93.8 | P | 93.2 | P | 94.6 | P | 93.3 | P | 93.5 | P | 93.1 | P | Std. Bind. | 5/29/03 | 92.0 – 96.0 |
| 2F2 | 92.2 | P | 92.6 | P | 92.2 | P | 93.6 | P | 91.9 | F | 92.2 | P | 92.0 | P | DG Surf. | 6/02/03 | 92.0 – 96.0 |

MIX PRODUCTION LEGEND:

| ABBREVIATION | MIX |
|---|---|
| **RB Bind.** | Rich bottom binder |
| **Std. Bind.** | Standard binder |
| **Poly Bind.** | Polymerized binder |
| **SMA Surf.** | Stone Matrix Asphalt Surface |
| **DG Surf.** | Dense-graded surface |

**NOTES**

- * - Two sets of cores were taken at these locations – one after the first day's paving, and one after the second day's paving. BMPR tested only those cores taken after the first day's paving. Champaign Asphalt tested both cores at these locations. The values in the chart are the average of Champaign Asphalt's results.
- N/A – The original worksheet from Champaign Asphalt showed that the oven dry weight of this core was considerably higher than the saturated surface dry weight. The results were considered invalid and not reported.
- With the exception of the SMA surface, the maximum specific gravity (Gmm) used for calculation of these densities is that of the first day's production. However, the standard and polymerized binders were produced on two separate days. The Gmm used for density calculations on the second day's production of these mixes was an average of the first and second day's production Gmm's.
- For the SMA surface mix, the historical average Gmm from the I-70 production was used in the density calculations. The SMA placed on I-70 was stored in a silo for 1.5 hours prior to placement. Similarly, the SMA placed at ATREL had a 1.5-hour haul (storage) time before placement. The SMA mix that was sampled during 6/02/03 production was sampled out of the truck at the plant with no storage time. The historical average Gmm from the I-70 production was more representative than the actual paving day production Gmm since it reflected the storage time.
- P/F refers to whether or not the core density was in the target density range. "P" means that the core density met the target density; "F" means that the core density failed to meet the target density.
- Cores were not taken at the sensor locations. BMPR core readings for the sensor location were developed based on a calculated offset. The raw nuclear density reading and the core density from location 2 (center of the lane, which is the sensor location) were compared and an offset calculated. This offset was applied to the raw nuclear reading at the sensor location to approximate the core density at the sensor location.
- Note that acceptance is based on core densities.

## ATREL NUCLEAR DENSITY SUMMARY

| ID | BMPR | | | | | | | | CHAMPAIGN ASPHALT | | | | | | III. PRODUCTION | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 % den. | P/F | 2 % den. | P/F | 3 % den. | P/F | SENSOR % | P/F | 1 % den. | P/F | 2 % den. | P/F | 3 % den. | P/F | MIX | DATE LAID | TARGET DENSITY |
| 1A1 | 93.8 | F | 94.9 | P | 96.0 | P | 94.1 | P | 92.6 | F | 94.0 | P | 94.8 | P | RB Bind. | 5/29/03 | 94.0 – 97.0 |
| 1A2 | 94.9 | P | 94.1 | P | 93.1 | P | 93.3 | P | 92.1 | P | 93.0 | P | 93.0 | P | Std. Bind. | 5/29/03 | 92.0 – 96.0 |
| 1A3 | 96.3 | F | 94.9 | P | 95.4 | P | 95.3 | P | 94.5 | P | 93.7 | P | 94.8 | P | Std. Bind. | 5/30/03 | 92.0 – 96.0 |
| 1A4 | 95.1 | P | 95.9 | P | 95.3 | P | 96.2 | F | 94.4 | P | 94.6 | P | 95.6 | P | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 1A5 | 94.2 | P | 95.7 | P | 95.5 | P | 95.1 | P | 93.3 | P | 94.1 | P | 93.9 | P | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 1A6 | 93.7 | P | 89.3 | F | 92.7 | P | 90.3 | F | 92.6 | F | 89.0 | F | 92.2 | F | SMA Surf. | 6/02/03 | 93.5 – 97.4 |
| 2A1 | 95.8 | P | 95.5 | P | 94.7 | P | 95.6 | P | 94.2 | P | 95.0 | P | 95.8 | P | RB Bind. | 5/29/03 | 94.0 – 97.0 |
| 2A2 | 93.8 | P | 95.7 | P | 93.7 | P | 94.7 | P | 92.2 | P | 93.3 | P | 91.8 | F | Std. Bind. | 5/29/03 | 92.0 – 96.0 |
| 2A3 | 94.4 | P | 95.5 | P | 96.9 | F | 97.2 | F | 93.9 | P | 94.2 | P | 94.5 | P | Std. Bind. | 5/30/03 | 92.0 – 96.0 |
| 2A4 | 95.8 | P | 95.5 | P | 95.8 | P | 94.3 | P | 94.0 | P | 94.9 | P | 94.9 | P | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 2A5 | 92.8 | P | 94.7 | P | 93.1 | P | 94.5 | P | 92.3 | P | 92.6 | P | 91.3 | F | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 2A6 | 96.9 | P | 93.8 | P | 94.2 | P | 89.7 | F | 94.8 | P | 92.5 | F | 94.5 | P | SMA Surf. | 6/02/03 | 93.5 – 97.4 |
| 1B1 | 94.6 | P | 95.6 | P | 95.2 | P | 96.0 | P | 92.9 | P | 92.8 | P | 92.4 | P | Std. Bind. | 5/29/03 | 92.0 – 96.0 |
| 1B2 | 93.2 | P | 95.3 | P | 94.5 | P | 92.7 | P | 92.9 | P | 94.0 | P | 91.4 | F | Std. Bind. | 5/29/03 | 92.0 – 96.0 |
| 1B3 | 94.6 | P | 95.1 | P | 93.0 | P | 96.0 | P | 95.0 | P | 95.8 | P | 96.5 | F | Std. Bind. | 5/30/03 | 92.0 – 96.0 |
| 1B4 | 95.5 | P | 95.5 | P | 96.0 | P | 94.7 | P | 94.6 | P | 94.1 | P | 94.9 | P | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 1B5 | 93.5 | P | 94.7 | P | 93.7 | P | 94.1 | P | 92.1 | P | 93.9 | P | 93.0 | P | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 1B6 | 95.6 | P | 95.5 | P | 93.3 | P | 93.9 | P | 95.2 | P | 95.2 | P | 92.7 | P | DG Surf. | 6/02/03 | 92.0 – 96.0 |
| 2B1 | 91.0 | F | 96.1 | F | 92.4 | P | 93.7 | P | 91.7 | F | 94.6 | P | 93.6 | P | Std. Bind. | 5/29/03 | 92.0 – 96.0 |
| 2B2 | 93.5 | P | 92.9 | P | 93.4 | P | 94.1 | P | 90.5 | F | 91.0 | F | 92.1 | P | Std. Bind. | 5/29/03 | 92.0 – 96.0 |
| 2B3 | 96.9 | F | 97.2 | F | 94.4 | P | 97.1 | F | 95.1 | P | 97.5 | F | 92.8 | P | Std. Bind. | 5/30/03 | 92.0 – 96.0 |
| 2B4 | 96.1 | F | 96.1 | F | 95.3 | P | 94.9 | P | 94.9 | P | 95.3 | P | 93.6 | P | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 2B5 | 93.4 | P | 94.2 | P | 93.1 | P | 93.4 | P | 92.0 | P | 92.3 | P | 91.7 | F | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 2B6 | 96.5 | F | 94.5 | P | 97.0 | F | 95.2 | P | 97.0 | F | 94.1 | P | 95.0 | P | DG Surf. | 6/02/03 | 92.0 – 96.0 |
| 2D1 | 92.2 | P | 93.0 | P | 91.4 | F | 89.9 | F | 91.1 | F | 92.1 | P | 91.6 | F | Std. Bind. | 5/29/03 | 92.0 – 96.0 |
| 2D2 | 93.3 | P | 93.3 | P | 94.4 | P | 92.0 | P | 92.2 | P | 90.8 | F | 92.4 | P | Poly Bind. | 5/29/03 | 92.0 – 96.0 |
| 2D3 | 95.6 | P | 95.0 | P | 95.2 | P | 93.6 | P | 94.3 | P | 91.6 | F | 93.9 | P | Poly Bind. | 5/30/03 | 92.0 – 96.0 |
| 2D4 | 97.1 | F | 97.6 | F | 96.4 | F | 96.1 | F | 96.7 | F | 96.0 | P | 95.6 | P | DG Surf. | 6/02/03 | 92.0 – 96.0 |
| 2F1 | 89.8 | F | 91.9 | F | 91.2 | F | 92.7 | P | 90.5 | F | 91.5 | F | 90.1 | F | Std. Bind. | 5/29/03 | 92.0 – 96.0 |
| 2F2 | 92.5 | P | 93.3 | P | 92.9 | P | 94.2 | P | 92.3 | P | 92.8 | P | 92.1 | P | DG Surf. | 6/02/03 | 92.0 – 96.0 |

<u>MIX PRODUCTION LEGEND</u>:

| ABBREVIATION | MIX |
|---|---|
| **RB Bind.** | Rich bottom binder |
| **Std. Bind.** | Standard binder |
| **Poly Bind.** | Polymerized binder |
| **SMA Surf.** | Stone Matrix Asphalt surface |
| **DG Surf.** | Dense-graded surface |

**<u>NOTES</u>**

- With the exception of the SMA surface, the maximum specific gravity (Gmm) used for calculation of these densities is that of the first day's production. However, the standard and polymerized binders were produced on two separate days. The Gmm used for density calculations on the second day's production of these mixes was an average of the first and second day's production Gmm's.
- For the SMA surface mix, the historical average Gmm from the I-70 production was used in the density calculations. The SMA placed on I-70 was stored in a silo for 1.5 hours prior to placement. Similarly, the SMA placed at ATREL had a 1.5-hour haul (storage) time before placement. The SMA mix that was sampled during 6/02/03 production was sampled out of the truck at the plant with no storage time. The historical average Gmm from the I-70 production was more representative than the actual paving day production Gmm since it reflected the storage time.
- Champaign Asphalt's nuclear readings are uncorrected (raw) densities.
- BMPR's nuclear readings for locations 1, 2, and 3 and the sensor are "corrected" based on previous experience with this gauge. BMPR's gauge typically reads low in relation to cores, and so nuclear readings were "corrected" upward by using a known linear correction for this gauge.
- P/F refers to whether or not the core density was in the target density range. "P" means that the nuclear density met the target density; "F" means that the nuclear density failed to meet the target density.
- Champaign Asphalt did not run nuclear densities at the sensor location.
- Note that acceptance is based on core densities.

## CORE THICKNESS DATA SUMMARY

| ID | Core Thickness, in. Champaign Asphalt | | | Core Thickness, in. BMPR | | | Tensile Strength, psi BMPR | | | Strip Rating, (CA/FA) BMPR | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Loc. 1 | Loc. 2 | Loc. 3 | Loc. 1 | Loc. 2 | Loc. 3 | Loc. 1 | Loc. 2 | Loc. 3 | Loc. 1 | Loc. 2 | Loc. 3 |
| 1A1 | 3.0 * | 2.9 * | 4.25 * | 3.31 | 3.38 | 3.5 | 79.8 | 92.2 | 91.7 | 1 / 1 | 1 / 1 | 1 / 1 |
| 1A2 | 2.7 * | 2.2 * | 2.75 * | 2.69 | 2.38 | 2.75 | 97.8 | 96.3 | 100.3 | 1 / 1 | 1 / 1 | 1 / 1 |
| 1A3 | 3.05 | 2.9 | 2.45 | 3.38 | 2.88 | 3.19 | 116.5 | 101.1 | 90.8 | 1 / 1 | 1 / 1 | 1 / 1 |
| 1A4 | 2.05 | 2.35 | 2.45 | 2.19 | 2.69 | 2.19 | 144.2 | 112.8 | 138.6 | 1 / 1 | 1 / 1 | 1 / 1 |
| 1A5 | 2.6 | 2.7 | 3.0 | 2.75 | 2.88 | 3.0 | 120.8 | 113.9 | 119.0 | 1 / 1 | 1 / 1 | 1 / 1 |
| 1A6 | 2.37 | 2.25 | 2.25 | 2.31 | 2.19 | 2.19 | 132.3 | 116.3 | 122.1 | 1 / 1 | 1 / 1 | 1 / 1 |
| Sum | 16.77 | 17.3 | 20.15 | 17.63 | 18.4 | 19.82 | | | | | | |
| 2A1 | 3.2 * | 3.75 * | 3.93 * | 3.0 | 3.88 | 4.06 | 77.8 | 84.9 | 78.1 | 1 / 1 | 1 / 1 | 1 / 1 |
| 2A2 | 3.0 * | 3.05 * | 3.03 * | 3.0 | 3.13 | 3.13 | 103.3 | 109.4 | 95.7 | 1 / 1 | 1 / 1 | 1 / 1 |
| 2A3 | 2.65 | 2.7 | 2.5 | 2.81 | 2.94 | 2.75 | 132.9 | 142.9 | 138.9 | 1 / 1 | 1 / 1 | 1 / 1 |
| 2A4 | 1.8 | 1.75 | 1.85 | 2.0 | 2.0 | 2.0 | 140.1 | 161.3 | 163.4 | 1 / 1 | 1 / 1 | 1 / 1 |
| 2A5 | 2.2 | 2.0 | 2.05 | 2.19 | 2.13 | 2.19 | 108.5 | 117.6 | 106.6 | 1 / 1 | 1 / 1 | 1 / 1 |
| 2A6 | 2.7 | 2.62 | 2.9 | 2.56 | 2.63 | 2.81 | 145.9 | 133.9 | 143.5 | 1 / 1 | 1 / 1 | 1 / 1 |
| Sum | 15.55 | 15.87 | 16.26 | 15.56 | 16.71 | 16.94 | | | | | | |
| 1B1 | 3.8 * | 2.15 * | 3.3 * | 5.0 | 3.44 | 4.56 | 128.4 | 132.2 | 133.0 | 1 / 1 | 1 / 1 | 1 / 1 |
| 1B2 | 2.7 * | 2.7 * | 2.6 * | 2.0 | 2.19 | 2.0 | 93.4 | 112.4 | 97.6 | 1 / 1 | 1 / 1 | 1 / 1 |
| 1B3 | 2.15 | 3.2 | 3.2 | 3.44 | 3.56 | 3.25 | 101.7 | 125.8 | 106.6 | 1 / 1 | 1 / 1 | 1 / 1 |
| 1B4 | 3.05 | 2.0 | 2.05 | 2.25 | 2.13 | 2.25 | 133.1 | 163.7 | 140.4 | 1 / 1 | 1 / 1 | 1 / 1 |
| 1B5 | 2.6 | 2.45 | 2.35 | 2.63 | 2.5 | 2.5 | 92.0 | 121.4 | 103.4 | 1 / 1 | 1 / 1 | 1 / 1 |
| 1B6 | 2.12 | 2.12 | 2.12 | 2.13 | 2.06 | 2.06 | 129.5 | 109.2 | 88.6 | 1 / 1 | 1 / 1 | 1 / 1 |
| Sum | 16.42 | 14.62 | 15.62 | 17.45 | 15.88 | 16.62 | | | | | | |
| 2B1 | 3.8 * | 3.75 * | 4.0 * | 4.0 | 3.88 | 3.69 | 105.4 | 98.7 | 90.9 | 1 / 1 | 1 / 1 | 1 / 1 |
| 2B2 | 3.1 * | 3.1 * | 3.12 * | 3.19 | 3.19 | 3.25 | 102.6 | 99.1 | 78.1 | 1 / 1 | 1 / 1 | 1 / 1 |
| 2B3 | 2.4 | 2.4 | 2.6 | 2.75 | 2.63 | 2.63 | 135.8 | 140.4 | 130.7 | 1 / 1 | 1 / 1 | 1 / 1 |
| 2B4 | 1.9 | 1.8 | 2.05 | 2.06 | 2.0 | 2.13 | 144.2 | 165.5 | 135.5 | 1 / 1 | 1 / 1 | 1 / 1 |
| 2B5 | 2.2 | 2.15 | 2.4 | 2.31 | 2.25 | 2.31 | 113.9 | 118.8 | 104.7 | 1 / 1 | 1 / 1 | 1 / 1 |
| 2B6 | 2.25 | 2.25 | 2.2 | 2.25 | 2.13 | 2.13 | 132.0 | 119.6 | 135.5 | 1 / 1 | 1 / 1 | 1 / 1 |
| Sum | 15.65 | 15.45 | 16.37 | 16.56 | 16.08 | 16.14 | | | | | | |
| 2D1 | 2.83 * | 3.25 * | 3.55 * | 2.81 | 3.19 | 3.25 | 104.2 | 109.6 | 100.9 | 1 / 1 | 1 / 1 | 1 / 1 |
| 2D2 | 2.7 * | 2.35 * | 2.4 * | 2.88 | 2.75 | 2.63 | 104.6 | 97.2 | 108.1 | 1 / 1 | 1 / 1 | 1 / 1 |
| 2D3 | 2.25 | 2.3 | 2.1 | 2.38 | 2.38 | 2.25 | 110.6 | 92.7 | 120.7 | 1 / 1 | 1 / 1 | 1 / 1 |
| 2D4 | 1.87 | 1.9 | 1.87 | 1.81 | 1.81 | 1.81 | 114.9 | 129.0 | 119.6 | 1 / 1 | 1 / 1 | 1 / 1 |
| Sum | 9.65 | 9.8 | 9.92 | 9.88 | 10.13 | 9.94 | | | | | | |
| 2F1 | 2.62 | 2.77 | 2.87 | 2.63 | 2.88 | 2.81 | 124.3 | 98.7 | 101.2 | 1 / 1 | 1 / 1 | 1 / 1 |
| 2F2 | 2.3 | 2.45 | 2.25 | 2.19 | 2.81 | 2.25 | 112.4 | 116.3 | 107.5 | 1 / 1 | 1 / 1 | 1 / 1 |
| Sum | 4.92 | 5.22 | 5.12 | 4.82 | 5.69 | 5.06 | | | | | | |

**NOTES**

- * - Two sets of cores were taken at these locations – one after the first day's paving, and one after the second day's paving. BMPR tested only those cores taken after the first day's paving. Champaign Asphalt tested both cores at these locations. The values in the chart are the average of Champaign Asphalt's results.
- Tensile strength and strip rating data is from BMPR. Champaign Asphalt did not run these tests.
- Split tensile tests were run on unconditioned cores. Tensile strengths and strip ratings were calculated based on IDOT's test procedure.
- Strip ratings are run on cores immediately after the split tensile test and refer to the percent of coarse aggregate and fine aggregate that show stripping. For the coarse aggregate, a rating of 1 signifies that less than 10% of the coarse aggregate particle area is stripped; a rating of 2 signifies that between 10% and 40% is stripped; and a rating of 3 signifies that greater than 40% of the entire area of coarse aggregate particles is stripped. For the fine aggregate, a rating of 1 signifies that less than 10% of the coarse aggregate particle area is stripped; a rating of 2 signifies that between 10% and 25% is stripped; and a rating of 3 signifies that greater than 25% of the entire area of coarse aggregate particles is stripped.

# APPENDIX C

# SPLIT SAMPLE TEST RESULTS FOR CHAMPAIGN ASPHALT AND IDOT

# CHAMPAIGN ASPHALT BULK SPLIT SAMPLE RESULTS

MIX TYPE: Rich Bottom Binder

MIX NUMBER: 85 BIT 1114

LAYDOWN DATE: May 29, 2003

MAXIMUM SPECIFIC GRAVITY (Gmm): 2.449

PERCENT VOIDS: 1.0

| IGNITION OVEN RESULTS (Washed Gradation) | |
|---|---|
| SIEVE (mm) | % PASSING |
| 19.0 | 96 |
| 12.5 | 81 |
| 9.5 | 70 |
| 4.75 | 42 |
| 2.36 | 25 |
| 1.18 | 16 |
| 0.60 | 11 |
| 0.30 | 8 |
| 0.15 | 7 |
| 0.075 | 5.5 |
| % AC | 5.4 |

# CHAMPAIGN ASPHALT BULK SPLIT SAMPLE RESULTS

MIX TYPE: Standard Binder

MIX NUMBER: 85 BIT 1112

LAYDOWN DATE: May 29, 2003

MAXIMUM SPECIFIC GRAVITY (Gmm): 2.492

PERCENT VOIDS: 3.3

| IGNITION OVEN RESULTS (Washed Gradation) | |
|---|---|
| SIEVE (mm) | % PASSING |
| 19.0 | 98 |
| 12.5 | 77 |
| 9.5 | 62 |
| 4.75 | 36 |
| 2.36 | 22 |
| 1.18 | 14 |
| 0.60 | 10 |
| 0.30 | 8 |
| 0.15 | 6 |
| 0.075 | 4.9 |
| % AC | 4.4 |

# CHAMPAIGN ASPHALT BULK SPLIT SAMPLE RESULTS

MIX TYPE: Standard Binder

MIX NUMBER: 85 BIT 1112

LAYDOWN DATE: May 30, 2003

MAXIMUM SPECIFIC GRAVITY (Gmm): 2.483

PERCENT VOIDS: 1.9

| IGNITION OVEN RESULTS (Washed Gradation) | |
|---|---|
| SIEVE (mm) | % PASSING |
| 19.0 | 97 |
| 12.5 | 75 |
| 9.5 | 62 |
| 4.75 | 39 |
| 2.36 | 25 |
| 1.18 | 16 |
| 0.60 | 11 |
| 0.30 | 9 |
| 0.15 | 7 |
| 0.075 | 5.6 |
| % AC | 4.8 |

# CHAMPAIGN ASPHALT BULK SPLIT SAMPLE RESULTS

| | |
|---|---|
| MIX TYPE: | Polymerized Binder |
| MIX NUMBER: | 85 BIT 1111 |
| LAYDOWN DATE: | May 29, 2003 |
| MAXIMUM SPECIFIC GRAVITY (Gmm): | 2.490 |
| PERCENT VOIDS: | 3.7 |

| IGNITION OVEN RESULTS (Washed Gradation) | |
|---|---|
| SIEVE (mm) | % PASSING |
| 19.0 | 97 |
| 12.5 | 69 |
| 9.5 | 58 |
| 4.75 | 34 |
| 2.36 | 20 |
| 1.18 | 12 |
| 0.60 | 8 |
| 0.30 | 5 |
| 0.15 | 4 |
| 0.075 | 3.2 |
| % AC | 4.2 |

# CHAMPAIGN ASPHALT BULK SPLIT SAMPLE RESULTS

MIX TYPE: Polymerized Binder

MIX NUMBER: 85 BIT 1111

LAYDOWN DATE: May 30, 2003

MAXIMUM SPECIFIC GRAVITY (Gmm): 2.491

PERCENT VOIDS: 2.9

| IGNITION OVEN RESULTS (Washed Gradation) | |
|---|---|
| SIEVE (mm) | % PASSING |
| 19.0 | 99 |
| 12.5 | 74 |
| 9.5 | 62 |
| 4.75 | 35 |
| 2.36 | 22 |
| 1.18 | 13 |
| 0.60 | 9 |
| 0.30 | 6 |
| 0.15 | 5 |
| 0.075 | 4.0 |
| % AC | 4.4 |

# CHAMPAIGN ASPHALT BULK SPLIT SAMPLE RESULTS

MIX TYPE: Dense Graded Surface

MIX NUMBER: 85 BIT 1113

LAYDOWN DATE: June 2, 2003

MAXIMUM SPECIFIC GRAVITY (Gmm): 2.451

PERCENT VOIDS: 5.1

| IGNITION OVEN RESULTS (Washed Gradation) | |
|---|---|
| SIEVE (mm) | % PASSING |
| 19.0 | 100 |
| 12.5 | 100 |
| 9.5 | 97 |
| 4.75 | 58 |
| 2.36 | 33 |
| 1.18 | 23 |
| 0.60 | 15 |
| 0.30 | 7 |
| 0.15 | 4 |
| 0.075 | 3.6 |
| % AC | 5.6 |

# CHAMPAIGN ASPHALT BULK SPLIT SAMPLE RESULTS

MIX TYPE: SMA Surface

MIX NUMBER: 85 BIT 3809

LAYDOWN DATE: June 2, 2003

MAXIMUM SPECIFIC GRAVITY (Gmm): 2.910

PERCENT VOIDS: 2.9

| IGNITION OVEN RESULTS (Washed Gradation) | |
|---|---|
| SIEVE (mm) | % PASSING |
| 19.0 | 100 |
| 12.5 | 90 |
| 9.5 | 77 |
| 4.75 | 31 |
| 2.36 | 20 |
| 1.18 | 15 |
| 0.60 | 12 |
| 0.30 | 11 |
| 0.15 | 10 |
| 0.075 | 8.3 |
| % AC | 5.5 |

# BMPR BULK SPLIT SAMPLE RESULTS

MIX TYPE: Rich Bottom Binder

MIX NUMBER: 85 BIT 1114

LAYDOWN DATE: May 29, 2003

MAXIMUM SPECIFIC GRAVITY (Gmm): 2.449 (AVERAGE OF 2 TESTS)

PERCENT VOIDS: 0.7 (AVERAGE OF 3 TESTS)

| REFLUX EXTRACTION RESULTS (Dry Gradation) | |
|---|---|
| SIEVE (mm) | % PASSING |
| 19.0 | 99 |
| 12.5 | 82 |
| 9.5 | 70 |
| 4.75 | 44 |
| 2.36 | 26 |
| 1.18 | 17 |
| 0.60 | 12 |
| 0.30 | 9 |
| 0.15 | 7 |
| 0.075 | 5.9 |
| % AC | 5.7 |

# BMPR BULK SPLIT SAMPLE RESULTS

MIX TYPE: Standard Binder

MIX NUMBER: 85 BIT 1112

LAYDOWN DATE: May 29, 2003

MAXIMUM SPECIFIC GRAVITY (Gmm): 2.497 (AVERAGE OF 2 TESTS)

PERCENT VOIDS: 3.5 (AVERAGE OF 2 TESTS)

| REFLUX EXTRACTION RESULTS (Dry Gradation) | |
|---|---|
| SIEVE (mm) | % PASSING |
| 19.0 | 99 |
| 12.5 | 76 |
| 9.5 | 66 |
| 4.75 | 38 |
| 2.36 | 23 |
| 1.18 | 15 |
| 0.60 | 11 |
| 0.30 | 8 |
| 0.15 | 6 |
| 0.075 | 5.2 |
| % AC | 4.7 |

# BMPR BULK SPLIT SAMPLE RESULTS

MIX TYPE: Standard Binder

MIX NUMBER: 85 BIT 1112

LAYDOWN DATE: May 30, 2003

MAXIMUM SPECIFIC GRAVITY (Gmm): 2.480 (AVERAGE OF 2 TESTS)

PERCENT VOIDS: 1.6 (AVERAGE OF 2 TESTS)

| REFLUX EXTRACTION RESULTS (Dry Gradation) | |
|---|---|
| SIEVE (mm) | % PASSING |
| 19.0 | 99 |
| 12.5 | 83 |
| 9.5 | 70 |
| 4.75 | 43 |
| 2.36 | 27 |
| 1.18 | 17 |
| 0.60 | 12 |
| 0.30 | 9 |
| 0.15 | 7 |
| 0.075 | 6.1 |
| % AC | 5.0 |

# BMPR BULK SPLIT SAMPLE RESULTS

MIX TYPE: Polymerized Binder

MIX NUMBER: 85 BIT 1111

LAYDOWN DATE: May 29, 2003

MAXIMUM SPECIFIC GRAVITY (Gmm): 2.489 (AVERAGE OF 2 TESTS)

PERCENT VOIDS: 3.8 (AVERAGE OF 2 TESTS)

| REFLUX EXTRACTION RESULTS (Dry Gradation) | |
|---|---|
| SIEVE (mm) | % PASSING |
| 19.0 | 98 |
| 12.5 | 74 |
| 9.5 | 62 |
| 4.75 | 37 |
| 2.36 | 22 |
| 1.18 | 14 |
| 0.60 | 10 |
| 0.30 | 7 |
| 0.15 | 5 |
| 0.075 | 4.4 |
| % AC | 4.4 |

# BMPR BULK SPLIT SAMPLE RESULTS

MIX TYPE: Polymerized Binder

MIX NUMBER: 85 BIT 1111

LAYDOWN DATE: May 30, 2003

MAXIMUM SPECIFIC GRAVITY (Gmm): 2.494 (AVERAGE OF 2 TESTS)

PERCENT VOIDS: 2.9 (AVERAGE OF 2 TESTS)

| REFLUX EXTRACTION RESULTS (Dry Gradation) | |
|---|---|
| SIEVE (mm) | % PASSING |
| 19.0 | 100 |
| 12.5 | 77 |
| 9.5 | 65 |
| 4.75 | 37 |
| 2.36 | 23 |
| 1.18 | 15 |
| 0.60 | 11 |
| 0.30 | 8 |
| 0.15 | 7 |
| 0.075 | 5.2 |
| % AC | 4.6 |

# BMPR BULK SPLIT SAMPLE RESULTS

MIX TYPE: Dense Graded Surface

MIX NUMBER: 85 BIT 1113

LAYDOWN DATE: June 2, 2003

MAXIMUM SPECIFIC GRAVITY (Gmm): 2.455 (AVERAGE OF 2 TESTS)

PERCENT VOIDS: 5.6 (AVERAGE OF 2 TESTS)

| REFLUX EXTRACTION RESULTS (Dry Gradation) | |
|---|---|
| SIEVE (mm) | % PASSING |
| 19.0 | 100 |
| 12.5 | 100 |
| 9.5 | 97 |
| 4.75 | 57 |
| 2.36 | 33 |
| 1.18 | 22 |
| 0.60 | 15 |
| 0.30 | 8 |
| 0.15 | 5 |
| 0.075 | 3.6 |
| % AC | 5.5 |

# BMPR BULK SPLIT SAMPLE RESULTS

MIX TYPE: SMA Surface

MIX NUMBER: 85 BIT 3809

LAYDOWN DATE: June 2, 2003

MAXIMUM SPECIFIC GRAVITY (Gmm): 2.890 (AVERAGE OF 4 TESTS)

PERCENT VOIDS: 2.3 (AVERAGE OF 2 TESTS)

| REFLUX EXTRACTION RESULTS (Dry Gradation) | |
|---|---|
| SIEVE (mm) | % PASSING |
| 19.0 | 100 |
| 12.5 | 91 |
| 9.5 | 77 |
| 4.75 | 31 |
| 2.36 | 19 |
| 1.18 | 13 |
| 0.60 | 10 |
| 0.30 | 9 |
| 0.15 | 8 |
| 0.075 | 6.4 |
| % AC | 5.1 |